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NUTRITIONAL STUDIES OF CELERY IN RELATION TO CERTAIN PHYSIOLOGICAL CHANGES IN COLD STORAGE[1]

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INTRODUCTION

Considerable experimental work has been done on the production of celery in the field. Experiments are being carried on year after year in an attempt to find which fertilizer or fertilizers produce the best results.

The celery acreage for the Province of Quebec has increased from 169 acres in 1930 to 760 acres in 1936. McKibbin and Stobbe (14) have shown that there are 40,000 to 50,000 acres of peat and muck soils within a radius of 45 to 65 miles of Montreal. Most of this area could produce good celery. However, figures show that for the years 1930–35 an average of 278½ cars of celery were imported each year into Montreal.

It has been shown that celery of good quality can be grown in Quebec. The weak point at present is to keep the produce in good condition in the storage until it will bring a high price or until it is required for consumption. With this in view the Quebec Refrigeration Committee undertook a rather extensive celery fertilizer experiment last summer near Ste. Clothilde de Chateauguay to determine if the different levels of nutrients had any effect on the keeping quality in cold storage. After the crop was harvested and the records of yield taken, from two to four crates from each plot were placed in the Montreal Harbour Cold Storage.

MATERIALS AND METHODS

The field experiment was based on a 4-8-16 fertilizer at the rate of one ton per acre. Nitrogen was supplied in the form of nitrate of soda and potash as the muriate form. This was accepted as the unit standard. The treatments were varied so that nitrogen, phosphorus and potash had three levels each, *viz.*, zero, once and twice the amount present in the 4-8-16 fertilizer. These three levels were arranged in all possible combinations, which gave 27 treatments (Table 1).

The celery was placed in the cold storage on October 1, 1937. Readings were taken on osmotic pressure, pithiness, colour and breakdown, and were taken at the following times: 50, 71, 96, 106, and 120 days after being placed in storage.

[1] Read before a meeting of the Horticultural Group of the C.S.T.A. at Ottawa, Ontario, June 27–July 2, 1938.
Reported from experiments conducted under the direction of the Quebec Refrigeration Committee (working committee on celery investigations), 1938.

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De Vries plasmolytic method was used to determine the osmotic pressures. This method was devised in 1884 and is based on the following considerations (13): The higher the osmotic pressure of the external solution above the osmotic pressure of the cell sap, the greater is the shrinkage of the protoplasm. On the other hand, the smaller the decrease in volume of the protoplasmic sac, the less it will withdraw from the cell wall, thus showing a smaller difference between the two pressures. If a concentration of the outer solution is found which causes but an incipient shrinking of the protoplasm, which is usually observed in some corner of the cell, one may then assume that this concentration of the outer solution balances the concentration of the cell sap within. Since the concentration of the outer solution is known, it is easy to calculate its osmotic pressure and from this the almost equal osmotic pressure of the cell sap.

Table 1.—Fertilizer treatments showing formulae and active ingredients in pounds per acre

Treatment	Formula	Nitrate of Soda	Superphosphate	Muriate of Potash
0-0-0	0-0-0	0	0	0
0-0-1	0-0-16	0	0	666.6
0-0-2	0-0-32	0	0	1333.3
0-1-0	0-8-0	0	800	0
0-1-1	0-8-16	0	800	666.6
0-1-2	0-8-32	0	800	1333.3
0-2-0	0-16-0	0	1600	0
0-2-1	0-16-16	0	1600	666.6
0-2-2	0-16-32	0	1600	1333.3
1-0-0	4-0-0	533.3	0	0
1-0-1	4-0-16	533.3	0	666.6
1-0-2	4-0-32	533.3	0	1333.3
1-1-0	4-8-0	533.3	800	0
1-1-1	4-8-16	533.3	800	666.6
1-1-2	4-8-32	533.3	800	1333.3
1-2-0	4-16-0	533.3	1600	0
1-2-1	4-16-16	533.3	1600	666.6
1-2-2	4-16-32	533.3	1600	1333.3
2-0-0	8-0-0	1066.6	0	0
2-0-1	8-0-16	1066.6	0	666.6
2-0-2	8-0-32	1066.6	0	1333.3
2-1-0	8-8-0	1066.6	800	0
2-1-1	8-8-16	1066.6	800	666.6
2-1-2	8-8-32	1066.6	800	1333.3
2-2-0	8-16-0	1066.6	1600	0
2-2-1	8-16-16	1066.6	1600	666.6
2-2-2	8-16-32	1066.6	1600	1333.3

The problem then is to find a concentration of the external solution that produces only incipient plasmolysis. For this purpose a series of solutions of increasing concentration was prepared, differing from one another by the same magnitude, for instance, by 0.01 mol. Thin sections of celery were placed in different solutions. The highest concentrations induced strong plasmolysis (Figure 1); the weakest, no plasmolysis whatever (Figure 2). Somewhere in between, a concentration was found which

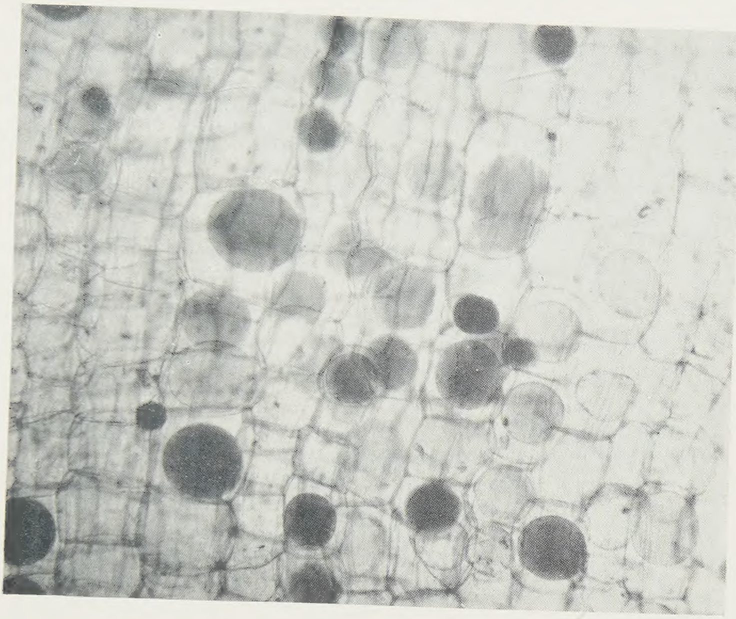

FIGURE 1. Strongly plasmolysed cells.

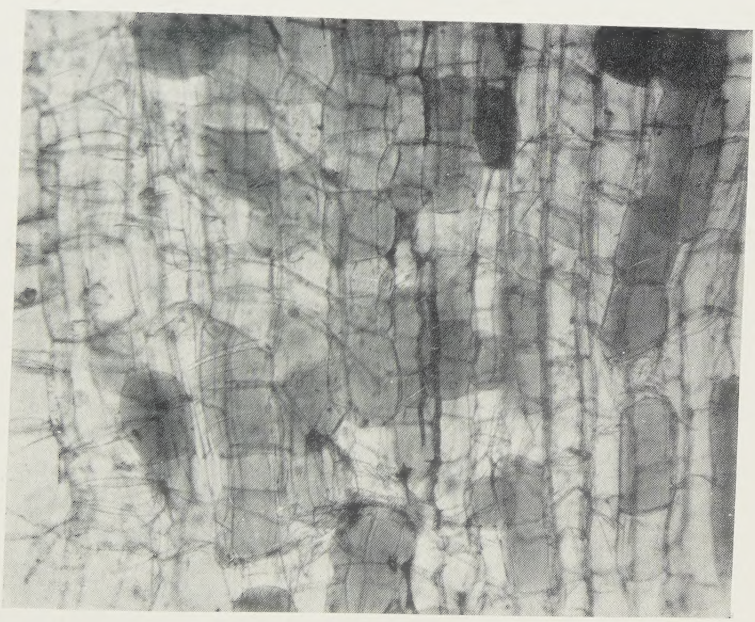

FIGURE 2. Stained cells showing no plasmolysis.

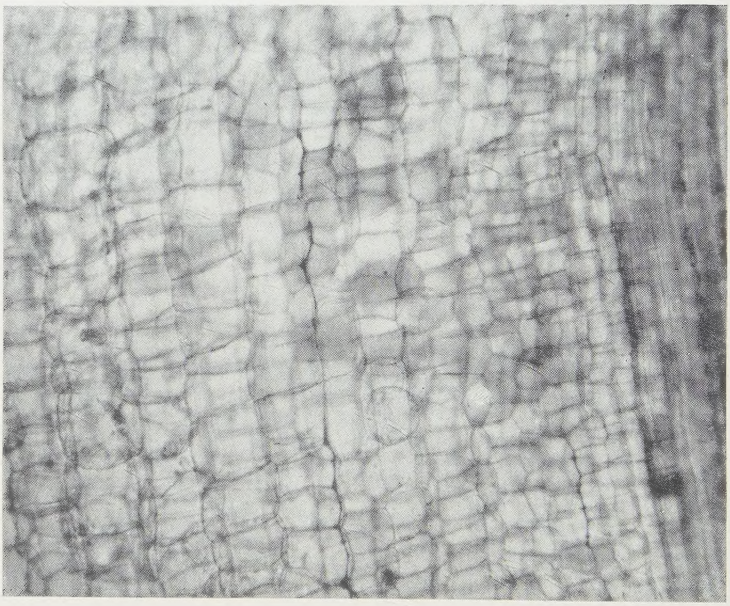

FIGURE 3. Cells showing incipient plasmolysis.

induced only the incipient stage of plasmolysis (Figure 3). The concentration of this solution corresponded to the molecular concentration of the cell sap.

Pithiness was measured by giving a number according to the size of the cavity and the number of stalks showing pithiness. For instance: solid petioles −0, faint trace of pithiness −1, cavity just discernible −2, cavity of fair size −3, and cavity large −4.

Earlier workers, particularly Austin and White (2) required that considerable pithiness be present before the plant was considered pithy. A stalk was not counted pithy unless the whole heart as well as the outer part was pithy. When the three or four outer petioles were somewhat pithy and the heart solid, the plant was counted solid.

In the present work, an attempt was made to differentiate between pithiness and non-pithiness. Indeed, even a single petiole showing only a trace of pithiness was recorded. In this way it was hoped that the pithiness might be determined as being due to treatments, senescence, or position of the petiole on the plant.

Colour was rated according to numerical standards, *e.g.:* dark green 4, green 3, light green 2, and blanched 1.

Breakdown was determined by weighing before and after trimming off the unmarketable parts. If a part of the petiole was rotted or had become soft and worthless through wilting, only the worthless part was removed, not the whole petiole as would have been done in commercial trimming.

The storage temperature was found to be 32.1 ± 4.06. This was determined by a recording thermometer which operated for a period of about four weeks between November 7 and December 10. It was impossible to determine the relative humidity accurately but it fluctuated between 93% and 97%.

The celery was remarkably free from disease.

REVIEW OF LITERATURE

Osmotic Pressure

Maximov (13) states that in some plants osmotic pressure is induced chiefly by sugars and organic acids. When starch is hydrolysed into sugar, the osmotic pressure is increased considerably.

Lewis and Tuttle (11) found that variation of the sugar content closely followed the variation of the osmotic pressures. They also found that the sugars show a decided concentration during the winter months.

Dixon and Atkins (7) state that the major part of the osmotic pressure of tissues is due to dissolved carbohydrates.

Magness (12) and others have reported a slight increase in the total quantity of sugar in the apple between the time of harvesting and the time when the fruit became soft.

Pithiness

Sandsten and White (17) and Austin and White (2) found that pithiness is hereditary and dates back to the parent plant.

Norton (16) states that pithiness is characterized by a lack of parenchyma, due in self-blanching varieties to heredity, to the propagation of an undesirable strain or to reversion, but in other forms it is probably due to unfavourable cultural conditions.

Early maturity in the field and too high a temperature in the store house cause pithiness, according to Mills (15).

Sayre (18) says that pithiness evidently is correlated with a breaking down of the parenchyma which leaves large open spaces through the centre of the stalk.

Emsweller (8) describes two kinds of pithiness. There is the type which is found throughout all the petioles, even in the young plants, and which is caused by a single dominant gene. The second type develops in the outer petioles with maturity.

Binkley (3) attributes pithiness to growth checks, poorly selected seed, to too rapid a growth following a growth check, and to severe injury by late blight and by web-worm.

EXPERIMENTAL RESULTS

Osmotic Pressure

De Vries plasmolytic method was used. Incipient plasmolysis, the stage when 50% show signs of plasmolysis and 50% do not, was considered as giving a fairly good reading of the osmotic concentration. Maximov (13) shows that the isotonic value at incipient plasmolysis is necessarily a little higher at this stage than normally. However, since this difference is common to all the readings, this method was accepted as giving a fairly good measure of the osmotic pressure. It also has the advantage of being independent of the fluctuation of the water content.

There were no plants of the 2-0-0 treatment after the first of the year since only two crates of this treatment had been placed in storage and they were unfortunately used for another purpose. However the three remaining readings for this treatment were estimated by a method derived by Yates (20) to restore orthogonality and to make the estimate of the error more valid.

Lewis and Tuttle (11) and others claim that there is a rise in the osmotic pressure during the fall and winter seasons until it reaches a certain maximum and then gradually falls off. Some treatments showed a rise, a fall and then a rise to a maximum before the final decline. Others showed an almost steady decline from early in the season. However, when the average of all treatments is considered, a curve is produced which has its maximum about December 10 (Figure 4). This means that the sugar content is at its highest about the tenth of December and then falls off.

Careful study of Table 2 will reveal that there is considerable fluctuation in the osmotic values of the different treatments at different dates. There seems to be little consistency in these data as they stand. However when they are analysed statistically, they show definite results.

The data were analysed by Fisher's Analysis of Variance (9, 10) and the significance tested by the Distribution of z.

The difference in osmotic pressures between the outer and inner petioles was not found to be significant.

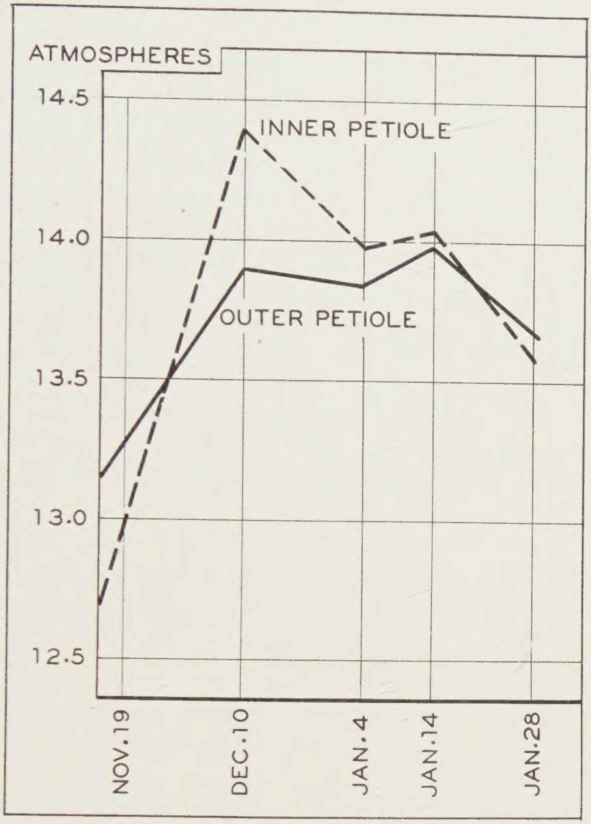

FIGURE 4. Osmotic pressures. Average of the 27 treatments.

Corbett and Thompson (6) have suggested that a progressive translocation of sugars proceeds from the external petioles to the heart during the cold storage of celery. The present data seem to show that this translocation did not take place in sufficient quantities to be significant.

Length of storage period, of course, is an important factor, as already pointed out.

The results indicate that on the average high nitrogen, low phosphorus and low potash give high osmotic pressures. However, there are complicating interactions which make it difficult to say which treatment is the best.

Pithiness

The data indicate that the position of the petioles on the plant, whether inner or outer, is highly significant. The outer petioles showed considerably more pithiness than the inner. However, it was found that pithiness did not increase with maturity or senescence, as Emsweller's second type of pithiness had done.

Phosphorus is the most important single factor which influences pithiness. With no phosphorus present, the amount of pithiness was very great. When 8% and 16% of phosphorus were applied, the amount

Table 2.—Osmotic values of inner and outer petioles of plants from the different fertilizer treatments at different dates

Treatment	Nov. 19		Dec. 10		Jan. 4		Jan. 14		Jan. 28	
	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner
0-0-0	.24	.21	.23	.23	.22	.22	.23	.23	.22	.21
0-0-1	.22	.19	.21	.22	.21	.22	.23	.23	.23	.22
0-0-2	.18	.20	.24	.25	.23	.23	.24	.23	.25	.25
0-1-0	.20	.18	.21	.23	.22	.23	.21	.22	.21	.21
0-1-1	.18	.17	.21	.22	.21	.22	.22	.20	.22	.22
0-1-2	.20	.17	.21	.22	.22	.22	.21	.21	.22	.22
0-2-0	.21	.21	.22	.23	.22	.22	.23	.23	.23	.23
0-2-1	.22	.21	.21	.23	.22	.22	.24	.24	.22	.22
0-2-2	.22	.21	.23	.24	.22	.22	.22	.23	.21	.21
1-0-0	.22	.22	.25	.25	.25	.25	.25	.25	.25	.25
1-0-1	.22	.22	.25	.25	.25	.25	.25	.25	.24	.24
1-0-2	.21	.20	.20	.21	.23	.22	.21	.21	.20	.20
1-1-0	.20	.21	.24	.25	.24	.25	.24	.24	.23	.23
1-1-1	.21	.20	.20	.20	.20	.21	.21	.21	.21	.20
1-1-2	.21	.20	.20	.20	.22	.21	.20	.21	.20	.19
1-2-0	.20	.19	.21	.22	.21	.21	.21	.21	.20	.20
1-2-1	.19	.19	.22	.23	.20	.21	.22	.21	.20	.20
1-2-2	.21	.21	.22	.23	.23	.22	.22	.21	.21	.21
2-0-0	.23	.23	.23	.24	.23	.24	.24	.24	.23	.24
2-0-1	.23	.22	.24	.25	.25	.26	.26	.27	.26	.26
2-0-2	.22	.23	.24	.26	.23	.23	.23	.23	.23	.23
2-1-0	.21	.20	.23	.24	.22	.22	.23	.24	.23	.23
2-1-1	.21	.21	.22	.23	.24	.24	.24	.24	.23	.23
2-1-2	.21	.22	.22	.22	.20	.20	.20	.21	.18	.19
2-2-0	.23	.22	.24	.25	.25	.25	.24	.24	.23	.24
2-2-1	.22	.19	.24	.25	.21	.21	.22	.22	.23	.23
2-2-2	.23	.22	.23	.24	.21	.21	.20	.21	.19	.19

of pithiness was considerably reduced, being smaller with the 16% than with the 8% but not significantly so. Nitrogen and potash did not show any significant differences.

White-Stevens (19) also found that nitrogen was not effective in causing pithiness.

The interactions of P × K and P × N are highly significant, whereas N × K is just barely significant.

Colour

Colour changes of the celery in cold storage were observed over a period of four months.

Phosphorus, nitrogen and potash are all highly significant though phosphorus is really outstanding.

When the three elements are lacking, the plants maintain quite a deep green colour, throughout the storage period.

The data would indicate that a medium amount of nitrogen and a medium to large amount of phosphorus and potash cause the petioles to blanch best in storage. Plants receiving this treatment would, of course, be large and would blanch in the field to a certain extent due to the petioles being covered by the abundant foliage.

Breakdown

Had the plants been weighed at the time that they were put in storage and again after they had been trimmed after being in storage for a certain length of time, a good idea of the amount of breakdown would have been obtained. However, the plants were not weighed on being put in the cold store so the author had to be content with weighing them as they came out of storage, both before and after trimming. These data were used in estimating the percentage of breakdown.

The Analysis of Variance revealed that treatments, phosphorus, and period of storage were all highly significant.

Phosphorus was the most important factor in influencing the amount of breakdown. The heavier application of phosphorus proved to be the one which gave the least amount of breakdown. However the difference in favour of the 16% over the 8% was not quite enough to be significant.

Four per cent nitrogen produced more breakdown than either the 0 or the 8% treatments. The higher percentage of nitrogen proved to be the best.

Potash did not produce significant differences in this respect.

Thus it is seen that a heavy application of nitrogen and a heavy application of phosphorus produced the smallest percentage of breakdown.

DISCUSSION

Abell (1) states that a high nitrogen content of the soil is necessary for good quality of celery. The data from this experiment are in agreement with this.

Contrary to popular belief, potash does not show up as being of particular importance to celery grown on muck soil, especially from the standpoint of keeping quality in cold storage. This is in direct variance with the results obtained by F. S. Browne (5) at the Ste. Clothilde Substation last summer. He found that when the plants received a side-dressing of 200 pounds of muriate of potash during the summer, the yield was substantially increased and the plants kept in much better condition in the storage till the end of December than did the plants which received the same fertilizer treatment except for the side-dressing. The author is at a loss as to how to reconcile these two differences since the material used by him was grown on muck only a few miles from Ste. Clothilde.

Phosphorus seems to be the most important in connection with keeping quality as determined by osmotic pressure, pithiness, colour and breakdown. Its level should be accurately adjusted since fluctuation in it in one direction or the other is most important, whereas fluctuations in either nitrogen or potash are not as important.

A number of correlations were calculated. The figures for yield of these fertilizer plots were taken from Bourque (4), Quebec bursary student working under the supervision of the Working Committee of the Quebec Refrigeration Committee.

The correlation coefficients obtained were tested by Table VA (9).

Thus there are negative correlations between yield and osmotic pressure, yield and colour, and yield and pithiness. Therefore as the yield

increases, colour and pithiness noticeably decrease, whereas the correlation between yield and osmotic pressure is not very high though it is significant. There seem to be a factor or factors apart from growth which affect osmotic pressures.

From Table 3, it is seen that breakdown, colour and pithiness all increase as the sugar content is increased, though none of the correlations are very high.

TABLE 3

Correlation between	Correlation coefficient	Cor. Coeff. Value P. 02	Cor. Coeff. Value P. 01
Osmotic concentration and breakdown	0.448	0.4451	0.4869
Osmotic concentration and yield	−0.438		
Osmotic concentration and pithiness	0.509		
Osmotic concentration and colour	0.623	0.4451	0.4869
Yield and colour	−0.804		
Yield and pithiness	−0.602		
Colour and pithiness	0.694		

Plants which maintain their green colour to a greater or lesser extent throughout storage seem to be more pithy than the lots which blanched more completely.

Bourque (4) in analysing the yield results of this experiment found that the 2-1-1 (8-8-16 fertilizer) treatment gave the best results. These present studies seem to indicate that of the 27 fertilizer treatments used in the experiment, the 2-1-1 is probably the best from the standpoint of keeping quality of celery in cold storage.

However, in the face of these physiological studies the 8-12-16 fertilizer might be recommended for trial. These results are based on one year's work and therefore are not altogether conclusive.

SUMMARY

1. Osmotic pressure was measured by De Vries plasmolytic method. The difference between outer and inner petioles was not found to be significant. The osmotic pressures reached a maximum about the tenth of December.

2. Pithiness was observed and recorded. The outer petioles showed more pithiness than the inner. Pithiness did not increase with senescence.

3. Colour was observed over a period of four months. There was quite a marked difference due to treatments.

4. Breakdown was determined. Phosphorus, treatments, and period of storage proved to be highly significant.

5. Phosphorus seems to be the element which requires careful adjustment, since it figures highly in each of the four studies. This will depend, probably, to a considerable extent on the phosphorus content in the soil.

6. Nitrogen fluctuations are not so important though a fairly high level should be maintained.

7. Potash does not seem to be as important as it sometimes is claimed to be, since in none of the four studies did it produce significant differences.

8. Increased yield gave decreased colour and pithiness and to a lesser extent decreased osmotic pressures.

9. Increased osmotic pressures gave increased pithiness, colour and breakdown, though the correlation is not very high.

10. Plants which kept their green colour throughout storage were on the average quite pithy.

11. These studies point to an 8-8-16 fertilizer as being the best of those used in the experiment, though the data might suggest an 8-12-16 fertilizer as being even better.

ACKNOWLEDGMENTS

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THE APPLICATION OF CONTROLLED ATMOSPHERES IN THE STORAGE OF FRUITS[1]

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It is apparent from observation that fruit suffering from physiological storage disorders is being marketed to quite a large extent. It is not uncommon to see apples on display during the winter suffering from superficial scald and similar disorders. In many cases, McIntosh apples on the market are being sold as high quality apples, but on cutting these open they are found to be suffering from core flush and other forms of internal breakdown. As long as these conditions are allowed to exist the demand for home grown fruits is bound to decrease.

The situation becomes more grave when we consider the probable increase in apple production in the next few years. According to surveys made by the Quebec Pomological Society, out of the 600,000 commercially grown apple trees in Quebec, 326,000 are non-bearing. Out of these non-bearing trees about 60% are McIntosh variety. If these figures are representative of Canada as a whole it is obvious that the trend of production is swinging to an excess, especially in the case of McIntosh.

One of the unfortunate features of this variety is that it holds its appearance sufficiently well in storage to permit marketing after the natural flavours have disappeared and the quality is low. Another point is that McIntosh, if stored at a temperature of 32° F. to obtain maximum storage life, develops core flush.

Core flush is definitely associated with low storage temperatures in the case of McIntosh apples. If core flush development is controlled by using a higher storage temperature a considerable loss in storage life results.

This is the point where a system of controlled atmospheres has proven to be of extreme value. With McIntosh apples an atmosphere of 7% CO_2 and 14% O_2 at 39° F. will extend the storage life to the same extent as 32° F. without the development of core flush. Thus the advantage in improving the marketing condition of McIntosh apples can readily be seen. Similarly the effect of gas storage (or controlled atmospheres) has been shown to be beneficial in the storage of other varieties of apples and pears. There is no reason to believe that it will not have some application in vegetables and other horticultural produce.

Controlled atmospheres in storage, as the name implies, is merely a control of the concentration of atmospheric gases. When fruits are stored in a gas tight chamber, the concentration of oxygen is reduced and carbon dioxide increased by the respiratory activity of the fruit. In order that the concentrations of these gases shall not reach a point where damage is caused to the fruit tissues, some control system must be devised. In most cases a simple ventilation system is all that is necessary. When subnormal amounts of oxygen are required a CO_2 absorber is used.

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This brings up the problem of balance between CO_2 and O_2 concentrations. It has been shown that lowering the concentration of oxygen decreases the respiratory activity. Furthermore, the lowered oxygen concentrations affect the respiratory reactions previous to glycolysis (Blackman—1928). This applies, of course, while the tissues are respiring aerobically.

Investigatory work carried out with the effect of controlled atmospheres on Bartlett pears has indicated that a balance between CO_2 concentration and oxygen concentrations should exist. It is then feasible to assume that if CO_2 acts as a depressant it would be in the form of a post-glycolytric narcotic. This is substantiated by the trend of respiratory quotients, particularly at the onset of gas storage injury. Be this as it may, the balance between oxygen decrease and CO_2 increase has been found to be important. Fortunately in most cases Canadian grown apples do sell under a balance brought out by the fruit themselves. Probably the only important exception is in Cox Orange variety of apples which requires a sub-normal oxygen mixture.

The next feature to be considered is absolute concentrations. The direct ill effect of concentrations is brought about by inducing a state of zymasis. In other words, the oxidative system must perform in such a manner that the substrates for respiration are completely oxidized. Partial oxidation results in the production and subsequent accumulation of such products as ethyl alcohol and acetaldehyde. If this state of metabolism exists for any length of time, necrosis of the tissues is the ultimate result. The physiological disorder resulting from these conditions has been referred to as brown heart. In many cases, however, zymasis may be induced only to a slight extent resulting in lack of quality and poor flavours. This upset in metabolism is the main consideration in the application of controlled atmosphere. The criteria used to foretell these circumstances are changes in respiratory quotient and detection of mal-flavours. We have resorted chiefly to the latter on the bases of reliability and convenience.

Thus the chief problem in the application of controlled atmosphere is presented *viz.:* to arrive at a controlled atmosphere which will produce maximum prolongation of storage life without a deleterious upset to the metabolism.

Our method of working on this problem is to expose fruit in small chambers to a continuous flow of gas of a given CO_2 and O_2 concentration (the balance being made up of nitrogen). These atmospheres are made up in a gas mixing chamber and compressed into a gas cylinder. A flow of 1 cu. ft. per day per chamber is permitted to pass over the fruit from these cylinders.

Examinations of the fruit made after removal from the chambers and being exposed to ripening conditions for one week have revealed some interesting facts, some of which have been indicated by other workers. In brief, the most salient of these are: (1) different varieties require different concentrations; (2) the same variety may require a different gas concentration at different temperatures; (3) different maturities of the same variety behave differently under the same gas mixtures at the same temperature.

As has been suggested, McIntosh is probably the most important variety (from the standpoint of results and commercial importance) and hence work has been concentrated on this particular variety. It was found that the best results, as mentioned at the outset, were obtained by exposing this variety to a $7 \pm \frac{1}{2}\%$ CO_2 and $14 \pm \frac{1}{2}\%$ O_2 at 39° F.

The next step was to reproduce these conditions in a semi-commercial way. This was carried out in a room holding about 150 bushels. These apples were marketed on the local market during the winter and comparisons were made with ordinary cold stored apples.

The results in brief from this latter trial indicate that McIntosh apples stored under these gas storage conditions were slightly superior in quality to the same apples stored at 32° F. and were slightly less advanced in maturity according to pressure tests. Humidity conditions being much better controlled, the fruit was more turgid and crisp. The most important feature was that no core flush developed in the gas stored apples whereas amounts varying from 20% to 25% were found at 32° F. normal storage (1936–37 Report).

Since such encouraging results were obtained by the use of a controlled atmosphere with McIntosh apples, a more minute investigation into the effect of apple type on subsequent quality of the fruit was made during the past year. The results obtained indicate that for maximum quality, well blushed fruit, well matured and of medium large size ($2\frac{1}{2}''$–$3''$) should be used. Early picked small fruit failed to develop maximum quality and aroma in storage.

It is hoped that by autumn of 1938 at least one commercial gas storage plant will be in operation for the storage of McIntosh apples. If this proves successful, the marketing situation of McIntosh should be improved, making it possible to offer fruit for sale which is not internally diseased and which is otherwise improved in quality. One feature must be emphasized and that is that controlled atmospheres should not be used for prolonging the storage life of McIntosh. At the present time McIntosh are being sold far beyond the end of their normal storage life. The chief aim should be to market McIntosh apples before the end of January at their highest standard quality. The logical and feasible method for doing this is by applying controlled atmospheric conditions judiciously.

STUDIES OF MEDIA FOR DETERMINING TOTAL BACTERIAL COUNTS OF ICE CREAM[1]

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INTRODUCTION

During recent years considerable interest has been taken in the development of methods for the bacteriological analysis of ice cream. Tentative methods for the bacteriological analysis of ice cream have been included, for the first time, in the sixth edition of *Standard Methods of Milk Analysis* (3). The medium recommended for the agar plate method of counting bacteria in ice cream is the standard nutrient agar used for years in milk control work. Previously, the Sub-Committee of the American Dairy Science Association on Bacteriological Methods of Examining Ice Cream (1, 2) had pointed out the rather wide use of the standard nutrient agar by Public Health Laboratories for ice cream analysis, but also mentioned other types of media useful for specific purposes. The reports (1, 2) of this Committee also mentioned that the addition of sugars to the media increased the number and size of colonies.

Several workers have pointed out that there are disadvantages when standard nutrient agar is used for the agar plate method of counting bacteria in ice cream. Fay (7) reported that large numbers of pin-point colonies appeared on low dilutions which were not present on higher dilutions, and found that the addition of sucrose or sterilized ice cream to the medium gave proportionate numbers of pin-point colonies on all dilutions. In later studies of the types of pin-point colonies appearing on ice cream plates, Fay (8) found that the addition of 1% glucose, sucrose, or lactose permitted the growth of 100% of 42 random cultures of pin-point colonies, whereas on plain agar 38.1% showed no growth and 16.7% had less than half normal growth when incubated at a temperature of 37° C. for 48 hours. Fay concluded that many of the organisms from ice cream that produced pin-point colonies were thermotolerant saccharophilic types rather than thermophilic. Fabricius and Hammer (6) observed large discrepancies in some cases in the counts on different dilutions when standard agar was used for plating ice cream. They pointed out the advantage of the addition of 1% sucrose to standard agar to enlarge the size of the colonies and to give greater uniformity in counts on different dilutions. These workers also found that the addition of sucrose to the medium increased the counts, especially on high count ice cream. At the Iowa Experiment Station the sucrose agar has been adopted for the analysis of ice cream by the agar plate method.

The Committee on Laboratory Methods of the International Association of Dairy and Milk Inspectors (9) reported on a trial of the comparative merits of standard nutrient agar and the same agar plus 1% saccharose, in which 8 members of the Committee collaborated. In all cases higher

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counts, ranging from 0.5 to 57% greater, were reported on saccharose agar than on the plain agar. This report indicated that the use of saccharose agar yielded larger colonies and fewer pin-point colonies, and some members reported that there was better agreement between counts obtained on different dilutions of the same sample.

In 1935 Bowers and Hucker (5) suggested the use of tryptone glucose skimmilk agar for counting bacteria in market milk. They found the new medium gave larger colonies with a minimum of pin-point colonies. Counts were higher than on standard nutrient agar with all classes of market milk although the differences were not as great with low count as with high count milk. It has been suggested that the tryptone glucose medium be used instead of standard nutrient agar for milk control work.

Phelan (10) reported on the bacteria counts of 21 samples of ice cream when tryptone glucose milk agar was used as compared to standard agar. He found that with the tryptone glucose agar there was a considerable increase over the counts on standard agar when plates were inclubated at 32° C. and a much greater increase on tryptone glucose agar at 32° C. than on standard agar at 37° C. Babel (4) in a study of different media for counting bacteria in ice cream found that tryptone glucose milk agar gave higher average counts in all ranges of counts than standard nutrient agar or standard nutrient agar plus 1% sucrose. This worker found that the addition of 1% sucrose to standard agar tended to increase the counts except for the samples having counts between 100,000 and 500,000 bacteria per cc. Both the tryptone glucose and sucrose agars tended to increase the size of the colonies and gave greater uniformity in the counts of duplicate plates. Incubation temperatures were not reported.

Since the studies presented herein were completed, Robertson (11) has shown that tryptone glucose agar gave higher counts for ice cream samples than standard nutrient agar at incubation temperatures of both 37° C. and 32° C., but that lowering the temperature of incubation from 37° C. to 32° C. had a greater effect on increasing the counts than the change of medium. Yale and Hickey (13) in a study of 112 samples of ice cream show wide variations in the counts when plated on standard nutrient agar at 37° C. as compared to the counts on tryptone glucose agar at 32° C. They conclude that standard nutrient agar at 37° C. is a poor instrument to determine the bacterial quality of ice cream, as the counts on standard agar do not represent a constant proportion of the total number of bacteria capable of development.

Wright (12), in studying organisms of the *S. thermophilus* group isolated from pasteurized milk, found that the addition of glucose, lactose or sucrose to the medium had a beneficial effect in giving counts of reasonable agreement with colonies of good size. With some organisms, however, the fermentable monosaccharides, as glucose, did not promote growth but the addition of disaccharides, as sucrose and lactose, gave heavy rapid growth from small inocula.

THE OBJECT OF THE WORK

The object of this work was to accumulate further comparative data: (1) on the relative values of standard nutrient agar, standard nutrient agar plus 1% sucrose, and tryptone glucose skimmilk agar for determining

total bacteria counts of ice cream; (2) on the proportion of pin-point colonies that appear on the different media; and (3) on the uniformity of the counts on different dilutions with the same medium.

EXPERIMENTAL METHODS

All media used in these comparisons were prepared from the dehydrated media of the Digestive Ferments Company. The same batch of Bacto nutrient agar, Standard Methods, was used for comparative purposes, to one part of which was added 1% sucrose just previous to tubing. In the preparation of the sucrose agar, ordinary cane sugar was usually added, but for a few lots Difco standardized saccharose was used. The tryptone glucose agars were supplied in two forms according to the formula of Bowers and Hucker (5). In one lot the skimmilk was already present in dehydrated form, but in the other it was necessary to add 5 cc. of fresh skimmilk per litre just before tubing.

The volumetric basis was used in plating the ice cream, and all dilutions were poured in duplicate for each medium. The dilutions were prepared by adding 10 cc. of melted ice cream to 90 cc. sterile water blanks, and other dilutions were prepared from this dilution. For all samples, dilutions of 1 : 100, 1 : 1000 and 1 : 10,000 were plated from the same dilution blanks for each medium. The agar was poured as soon as all the plates for each sample had been prepared, and, in general, the different media were poured in rotation to compensate for variation in time in which the ice cream was held in dilution water. Plates were incubated at 37° C. for 48 hours.

In counting the plates, all the colonies visible to the naked eye were marked off with a wax pencil when counted, and then re-examined with a lens. Colonies visible only with the lens were considered to be pin-point colonies. In many cases the plates of different dilutions for each medium were counted and recorded, especially when any discrepancies in the counts of different dilutions were apparent.

In subsequent discussion of the different media, standard nutrient agar will be referred to as standard agar, standard nutrient agar plus 1% sucrose as sucrose agar, and tryptone glucose milk agar as tryptone agar.

RESULTS

Comparative counts secured on four different media for 53 samples, and on 3 media for 29 samples of ice cream of various flavours and from many different Canadian ice cream plants are presented in Table 1.

A study of the data from the first 53 samples indicated such close agreement between the counts on the two tryptone agars that the use of tryptone agar to which fresh skimmilk had been added was discontinued. Additional counts for the other three media were obtained on 29 samples. Of the first 53 samples analyzed, the highest counts for 22 samples were obtained on sucrose agar; the tryptone agar and standard agar gave highest counts on 12 samples each; and the tryptone agar to which fresh skimmilk was added gave the highest counts for 7 samples. For 26 samples the lowest counts were found on standard agar, while 14 samples had low counts on the tryptone agar to which fresh skimmilk had been added. In only three cases was the low count obtained on sucrose agar. Comparing

TABLE 1.—COMPARATIVE TOTAL BACTERIA COUNTS OF ICE CREAM ON DIFFERENT MEDIA

Sample no.	Standard nutrient agar	Standard nutrient agar + 1% sucrose	Tryptone glucose agar + 5 cc. fresh skim-milk per litre	Tryptone glucose milk agar
1	30,400	32,500	28,900	33,400
2	286,500	343,500	102,500	141,500
3	900	1,350	700	850
4	50,000	57,000	78,000	73,000
5	2,200	2,000	1,500	600
6	190,000	135,000	169,000	160,000
7	41,000	29,000	38,000	28,000
8	49,000	75,000	84,000	105,000
9	5,500	8,200	11,300	18,100
10	185,000 E	350,000	360,000	490,000
11	205,000	315,000	272,000	300,000
12	80,000 E	80,000 E	94,400 E	106,500 E
13	91,000	107,000	106,000	110,000
14	45,000	54,000	46,000	53,000
15	29,000	35,500	36,500	44,000
16	18,700	22,500	10,400	24,800
17	47,500	66,500	58,000	58,500
18	2,100	2,600	1,950	2,000
19	109,500	186,500	91,500	115,500
20	37,000	40,500	56,000	53,500
21	2,100	2,800	2,300	1,800
22	57,000	54,500	44,500	37,000
23	13,900	14,400	12,000	11,900
24	10,800	16,500	21,200	19,100
25	36,000	90,000	65,000	73,500
26	11,300	9,000	8,900	10,100
27	425,000	435,000	305,000	350,000
28	7,000	5,300	4,500	4,800
29	32,000	39,500	43,000	40,500
30	3,570,000	4,885,000	4,260,000	4,580,000
31	161,000	266,000	230,500	230.500
32	322,000 E	515,000	480,000	415,000
33	7,200	6,900	5,950	6,600
34	36,950	28,750	27,050	26,900
35	185,000	910,000	935,000	1,050,000
36	87,000	81,000	87,500	78,000
37	111,000	115,500	87,500	92,500
38	185,000	224,500	161,000	146,000
39	380,000	675,000	650,000	605,000
40	60,000	83,000	69,500	79,000
41	27,200	22,800	24,300	23,400
42	33,000	47,000	44,000	53,000
43	223,000	228,000	125,000	197,000
44	26,000	28,000	29,000	30,500
45	44,500	53,000	60,000	71,500
46	1,110,000	2,180,000	990,000	850,000
47	1,030.000	1,160,000	1,280,000	870,000
48	2,060,000	2,890,000	2,830,000	2,540,000
49	93,000	85,000	60,000	62,000
50	320,000	440,000	360,000	290,000
51	14,800	14,600	13,500	13,800
52	330,000	725,000	790,000	685,000
53	24,000	18,000	15,000	17,000
54	186,000	1,160,000		1,160,000
55	26,000	36,000		39,000
56	27,000	28,200		25,800
57	26,800	17,200		13,800
58	16,500	15,100		9,200

E = Estimated.

TABLE 1.—COMPARATIVE TOTAL BACTERIA COUNTS OF ICE CREAM ON DIFFERENT MEDIA—*Concluded*

Sample no.	Standard nutrient agar	Standard nutrient agar + 1% sucrose	Tryptone glucose agar + 5 cc. fresh skim-milk per litre	Tryptone glucose milk agar
59	23,800	26,300		26,100
60	71,500	72,000		70,000
61	341,000	570,000		410,000
62	186,000	510,000		310,000
63	2,510,000	4,510,000		3,250,000
64	4,390,000	7,040,000		5,480,000
65	48,000	62,500		57,500
66	35,500	47,500		44,000
67	2,680,000	3,690,000		3,320,000
68	202,000	520,000		660,000
69	101,000	95,000		105,000
70	167,000	229,000		176,000
71	162,000	264,000		276,000
72	1,080,000	1,980,000		1,860,000
73	20,300	23,500		15,700
74	Uncountable on 1 : 1000, none on 1 : 10,000	5,750,000		4,760,000
75	61,000	153,000		128,000
76	470,000	635,000		186,000
77	17,200	21,200		20,200
78	32,800	25,800		54,000
79	37,500	37,500		28,000
80	2,130,000	3,300,000		2,860,000
81	390,000	1,680,000		1,550,000
82	440,000	2,395,000		2,060,000

E = Estimated.

standard agar, sucrose agar and tryptone agar (dehydrated milk included) for the 82 samples, it was found that on 44 samples highest counts were obtained on sucrose agar, while for 18 samples highest counts were obtained on the tryptone agar. In 15 cases counts were highest on standard agar, but for 12 of these samples the counts were relatively low, being less than 50,000 per cc. Comparing standard agar with the sucrose agar it was found that in all but 17 samples the counts were higher on the sucrose medium, and for 16 samples the counts were two or more times as great on the sucrose agar. Counts on the tryptone agar were greater than on standard agar for 50 samples, and in 12 cases the counts were nearly two or more times as great. Comparative counts on sucrose agar and on tryptone agar show that for 57 samples the counts were higher on the sucrose agar.

While many samples of low count ice cream did not show any marked differences in the counts on the various media, large discrepancies occurred in the counts for samples 35, 52, 54, 74, 81 and 82. Samples 10 and 32 would also have shown greater differences if the counts for the same dilutions on standard agar had been recorded instead of the estimated counts on the lower dilutions. In some of these samples there were fairly large discrepancies in the counts of different dilutions with standard nutrient agar.

In addition to the data obtained on the 82 samples shown in Table 1, further comparative counts were obtained on two different media for many

other samples. In all, comparative counts for sucrose agar and standard agar were secured on 198 samples, and comparisons on 105 samples were obtained on the sucrose and tryptone glucose agars.

A summary of the distribution of the high and low counts on the various media for all samples is given in Table 2.

TABLE 2.—SUMMARY OF HIGH AND LOW COUNTS ON DIFFERENT MEDIA

—	Total no. of samples	Standard nutrient agar	Standard nutrient agar + 1% sucrose	Tryptone glucose agar + 5 cc. fresh skimmilk per litre	Tryptone glucose milk agar
		Distribution of high Counts			
Series I	53	12	22	7	12
Series II	29	3*	22*	—	6*
Series III	198	57	141	—	—
Series IV	105	—	75	—	30
Series V	82	32	—	—	50
		Distribution of Low Counts			
Series I	53	26†	3†	14	11
Series II	29	20	2	—	7
Series III	198	141	57	—	—
Series IV	105	—	30	—	75
Series V	82	50	—	—	32

* Sample 54 had the same count on sucrose and tryptone agars and Sample 79 on sucrose and standard agar.

† Sample 12 had the same low count on two media.

These data show that the greatest number of high counts were obtained on the sucrose agar in all comparisons, and that the tryptone agar gave the next greatest number of high counts. The standard agar always had the greatest number of low counts of any of the media.

On examination of the plates of different media it was found that for many of the samples the colonies were larger and more easily counted on the sucrose and tryptone agars than on the standard agar. This observation is illustrated by the number of pin-point colonies which were present on the different media, as given in Table 3 for 53 of the samples included in Table 1. While the number of pin-point colonies varied considerably from one sample to another on all media, there usually were greater numbers of pin-point colonies on the standard agar than on the agars containing sugars. Some outstanding examples of the difference in the numbers of pin-point colonies on the various agars are to be found in samples 32 52, 68 and 72. The extreme case was with sample 72 where there was 100% pin-point colonies on standard agar and only 1% on sucrose agar and 2.7% on tryptone agar. In some of the cases the colonies were so small on the standard agar that it was difficult to make a count even with a lens. While there were a few instances of considerable variation in the percentage of pin-point colonies found on sucrose agar as compared with tryptone agar, in the majority of cases the percentages were much the same.

TABLE 3.—PER CENT PIN-POINT COLONIES ON DIFFERENT MEDIA

Sample no.	Standard nutrient agar	Standard nutrient agar + 1% sucrose	Tryptone glucose agar + 5 cc. fresh skimmilk per litre	Tryptone glucose milk agar
20	11.8	14.8	13.3	15.0
22	12.3	12.2	12.5	14.7
23	25.2	22.9	27.5	26.9
24	87.7	69.0	67.5	48.5
26	19.5	15.5	13.5	3.9
27	45.2	36.4	23.3	14.3
28	7.1	7.5	11.0	10.4
29	31.2	32.5	9.3	17.0
30	32.7	5.1	6.1	3.9
31	10.6	6.8	4.3	5.6
32	60.0	0.0	0.0	0.0
33	22.2	16.0	3.3	12.1
34	17.6	8.7	7.4	7.9
35	15.8	2.2	41.5	20.0
36	42.5	48.1	45.9	41.0
37	48.7	24.1	33.4	49.4
38	16.	10.2	10.6	8.2
39	5.0	1.5	6.1	5.0
40	36.6	8.4	17.1	17.7
41	16.2	11.8	11.5	12.8
42	45.4	19.1	20.5	22.6
43	14.8	9.2	12.8	9.1
47	18.4	10.3	1.6	2.3
49	20.4	15.3	8.3	3.2
50	12.5	11.3	16.6	44.8
51	6.8	3.4	3.7	0.0
52	63.0	5.5	2.6	30.4
53	14.6	18.8	13.3	10.0
54	15.6	4.3		0.0
55	32.5	13.2		6.6
56	38.2	15.3		13.2
57	21.3	22.1		24.6
58	71.5	17.2		35.9
59	18.1	11.0		5.0
60	9.0	11.1		5.7
61	95.0	33.3		22.5
62	94.0	35.3		29.0
63	28.3	13.3		8.6
64	45.7	20.0		8.7
65	20.8	6.4		22.4
66	31.5	8.5		11.4
68	75.1	7.7		9.1
69	53.5	6.3		5.7
70	71.2	15.7		18.7
71	5.0	4.2		26.0
72	100.0	1.0		2.7
73	6.9	3.9		9.0
77	13.4	3.0		3.7
78	56.2	7.0		22.6
79	9.4	9.4		3.6
80	18.9	18.5		10.8
81	63.2	10.8		11.6
82	50.0	13.8		8.7

Refering back to Table 1, it will be observed that the addition of sucrose to the standard agar or the use of tryptone agar did not affect the counts as much on the samples of low count ice cream as it did on the samples containing rather high numbers. The data presented in Tables 4

and 5, which give the average counts of all samples of ice cream and the distribution of the high and low counts on each media according to the dilution counted, illustrate this point very well. For the samples counted on the 1 : 100 dilution, standard agar gave a slightly higher average count than either of the other media. But for the 1 : 1,000 and 1 : 10,000 dilutions the average counts on both the media containing sugar were higher than on the standard agar and the percentage difference in the counts increased as the dilution increased. In Table 5 it will be noticed that the high counts were fairly evenly distributed between the three media with the 1 : 100 dilution, but with the 1 : 10,000 dilution not one sample had the highest count on standard agar, and in no case did the sucrose agar give the lowest count.

TABLE 4.—AVERAGE BACTERIA COUNTS OF ICE CREAM ON DIFFERENT MEDIA ACCORDING TO THE DILUTION COUNTED

Dilution plate counted	No. of samples	Standard nutrient agar	Standard nutrient agar + 1% sucrose	Tryptone glucose skimmilk agar
1 : 100	23	16,202	15,987	15,498
1 : 1,000	35	88,551	111,823	99,614
1 : 10,000	23	1,083,565	1,876,340	1,557,869

TABLE 5.—DISTRIBUTION OF HIGH AND LOW BACTERIA COUNTS ON DIFFERENT MEDIA ACCORDING TO THE DILUTION COUNTED

Dilution plate counted	Standard nutrient agar		Standard nutrient agar + 1% sucrose		Tryptone glucose skimmilk agar	
	No. high counts	No. low counts	No. high counts	No. low counts	No. high counts	No. low counts
1 : 100	9	7	9	2	5	14
1 : 1,000	6*	22*	17*	4*	13	10
1 : 10,000	0	18	20*	0	4*	5

* One high and one low count the same on two media.

Some examples of the lack of agreement between counts of different dilutions on standard nutrient agar are presented in Table 6. The data in this table show that while the greatest discrepancies in the counts usually occurred between the 1 : 1,000 and 1 : 10,000 dilutions, there were some marked differences in the counts between the 1 : 100 and 1 : 1,000 dilutions. It was found quite frequently that the counts on standard agar were very much less on the 1 : 10,000 dilution than on the 1 : 1,000 dilution, while on the media containing sugar the counts on the different dilutions were in reasonable agreement. Sample A6 is a good illustration of the variation in the counts obtained on different dilutions, the estimated count on the 1 : 1,000 dilution being 600,000 per cc. while on the 1 : 10,000 dilution it was only 90,000 per cc.

TABLE 6.—COMPARATIVE COUNTS OF VARIOUS DILUTIONS ON DIFFERENT MEDIA

Sample no.	Bacteria per cc. of ice cream							
	Standard nutrient agar		Standard nutrient agar + 1% sucrose		Tryptone glucose agar + 5 cc. fresh skimmilk per litre		Tryptone glucose milk agar	
	1 : 1000	1 : 10,000	1 : 1000	1 : 10,000	1 : 1000	1 : 10,000	1 : 1000	1 : 10,000
A 1	109,000	50,500	186,500	195,000	91,500	95,000	115,500	105,000
A 2	700,000 E	140,000	429,000	350,000				
A 3*	321,000 E*	24,000*	402,500	515,000	450,000	480,000	434,500	415,000
A 4	235,000	70,000	273,000	480,000				
A 5	910,000 E	185,000	686,000 E	910,000	812,000 E	935,000	825,000 E	1,050,000
A 6	600,000 E	90,000	+	1,320,000				
A 7	353,000	50,000	388,000	410,000				
A 8	200,000	10,000	227,000	240,000				
A 9	186,000	80,000	1,495,000 E	1,160,000			1,170,000 E	1,160,000
A 10	341,000	30,000	550,000	570,000			325,000	405,000
A 11	185,000	29,000	487,000	510,000			332,000	310,000
	1 : 100	1 : 1000	1 : 100	1 : 1000	1 : 100	1 : 1000	1 : 100	1 : 1000
A 12	30,400	15,500	32,500	30,000	28,900	23,000	33,400	23,500
A 13	49,500	25,000	52,800	52,000	55,400	78,000	55,600	73,000
A 14	80,000 E	49,000	73,000 E	75,000	83,000 E	84,000	87,000 E	105,000
A 15	185,000 E	4,000	+	350,000	+	360,000	+	490,000
A 16	35,000	15,000	30,000	40,000				
A 17	153,000 E	36,000	100,000 E	90,000				
A 18	136,000 E	52,000	78,000 E	74,000				
A 19	87,700 E	46,000	91,000 E	93,000				
A 20	120,000 E	31,000	144,000 E	128,000				
A 21	45,600	26,000	35,000	36,000			33,300	39,000
A 22	45,000	19,000	39,800	54,000	41,000	46,000	45,000	53,000

* = Counts made on 1 : 100 and 1 : 1000 dilutions.
E = Estimated.
+ = Plates uncountable.

It was interesting to observe that for those samples that showed wide discrepancies in the counts on standard agar for the higher dilutions, the 1 : 100 dilution plates appeared much the same for all media as far as colony growth was concerned. In many cases also the counts on the 1 : 1000 plates of the different media agreed reasonably well, but large discrepancies occurred in the counts on different media for the 1 : 10,000 dilution.

Where discrepancies occurred between the 1 : 100 and 1 : 1000 dilution plates with standard agar, the counts on the 1 : 1000 dilution in a number of cases were only about half those on the 1 : 100 dilution, while with the media containing sugar the counts on the 1 : 1000 dilution were usually slightly higher than on the 1 : 100 dilution. Quite large discrepancies in the counts between the 1 : 100 and 1 : 1000 dilutions on standard agar were found with samples A15, A17, A18 and A20. On many of the standard agar plates the colonies were very small and most difficult to count even with the aid of a lens.

DISCUSSION OF RESULTS

The results of this study indicate that the use of a medium which contains sugar is essential for the development and growth of many of the organisms present in ice cream. The addition of 1% sucrose to standard agar and the use of tryptone agar which contains glucose not only increased the size of colonies but also gave a greater number of colonies with many of the samples analysed. The addition of sucrose to standard agar and the use of tryptone glucose agar did not have the same effect on the counts of all samples, but the variations that occurred were probably due to differences in the bacterial flora of the ice cream samples and also to the importance of sucrose and glucose to the development of organisms present.

While the counts obtained on the sucrose and tryptone agars were comparable for all practical purposes with most samples, there were a few instances, as with samples 2, 46 and 76, where the counts on tryptone agar were significantly lower than on the sucrose agar. The selective characteristic of certain organisms surviving pasteurization for different sugars, particularly the disaccharides as shown by Wright (12), is a probable explanation of the lower counts on the medium containing glucose.

The better agreement of the counts on the higher dilutions with the media containing sugar than with the standard agar would indicate the advisability of adding sugar to the medium when analysing ice cream by the agar plate method. An entirely erroneous picture of the bacterial content of an ice cream sample may be obtained from the counts on standard agar if the numbers of colonies on the different dilutions fail to agree, as frequently occurs in high count ice cream. The comparative data obtained between the standard agar and sucrose agar, as regards size and numbers of colonies and agreement of the counts on different dilutions, corroborate the findings of Fabricius and Hammer (6). The results regarding the comparative counts on the tryptone agar and sucrose agar are not in agreement with those of Babel (4) who found that the logarithmic average of the counts on tryptone agar was higher than the logarithmic average of the counts on sucrose agar. In the work reported, both the arithmetical and the logarithmic averages of the counts on sucrose agar were higher than on the tryptone agar.

It is evident from the counts obtained on the tryptone agar that much less than 1% of sugar in the medium will give good results as to the size and numbers of colonies and agreement of counts on the different dilutions. In the tryptone agar only 0.1% of glucose is used as compared to 1% of sucrose in the standard agar, and for most samples the counts agreed reasonably well. However, as pointed out by Fabricius and Hammer (6) the use of 1% sucrose or some other sugar gives greater uniformity of the sugar concentration in the different plates as the amount of sugar carried into the dilutions by the ice cream does not greatly change the sugar content.

The increase in the size of the colonies and the decrease in pin-point colonies, which resulted in many cases when 1% sucrose was added to standard agar or where tryptone agar was used, made the counting of the plates much easier and quicker. This is an important factor in laboratories where many samples of ice cream are analyzed.

The data collected in this study as well as those of other investigators would indicate that a more constant proportion of the bacterial flora in

ice cream capable of developing colonies is obtained by the use of sucrose agar or tryptone agar than with standard agar.

SUMMARY

In the majority of cases, the two media which contained sugar gave higher plate counts on ice cream at 37° C. than did standard agar. Highest counts were obtained in the greatest number of samples with standard agar plus 1% sucrose, although the tryptone glucose milk agar was only slightly inferior.

The addition of sucrose to standard agar or the use of tryptone agar did not have as great an effect on the counts for low count ice cream as when relatively high numbers of bacteria were present.

There was no significant difference in the counts on tryptone agar when skimmilk was present in the dehydrated form or when fresh skimmilk was added to the melted agar before tubing.

Frequently large discrepancies appeared in the counts of different dilutions when standard agar was used for plating. The more serious discrepancies usually occurred between the 1:1000 and 1:10,000 dilutions but in a few instances the 1:100 and 1:1000 dilutions were affected. The addition of 1% sucrose to standard agar or the use of tryptone glucose skimmilk agar produced a reasonable agreement in the counts of all dilutions.

With the standard agar plus sucrose and tryptone glucose milk agar, counting was made easier due to the increased size of the colonies and the smaller percentage of pin-point colonies.

The data indicated that a medium containing sugar is necessary for the growth and development of many of the organisms present in ice cream.

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THE RELATION OF BROWNING ROOT ROT TO STEM RUST IN CAUSING INJURIES TO WHEAT

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It is common knowledge among plant pathologists and farmers alike that browning root rot (*Pythium* spp.) in Saskatchewan tends to delay the ripening of wheat. Careful observations on a number of study-fields showed the delay in maturity to vary between 3 and 21 days (4, p.230). This lengthening of the growing period still prevails in cases of apparent recovery which sometimes follow better growing conditions after the first appearance of the disease (3, p. 91). The significance of this retardation in exposing the crop to rust or frost damage has been stressed many times (3, p. 70).

Samples of healthy and diseased Marquis wheat plants were collected in a browning root-rot field at Saskatoon, in 1938, after stem rust *(Puccinia graminis tritici)* became epidemic and it was recognized that maturity of the crop was a big factor in determining rust injury. No definite plans had been made to study the relation between browning root rot and the incidence of rust. A field was selected, however, which had shown considerable browning root rot and in which the location of healthy and diseased areas was well known, as this field had been visited on three occasions in June when the browning symptoms were most conspicuous.

The field was visited on August 3 when healthy areas along the headland and in patches were observed to be quite mature. The kernels were in the dough stage and most of the straws were ripe. The plants showed only a trace of rust. In the diseased areas the kernels were in the late milk stage and the plants green. Rust on these plants was estimated at 20 to 30% extending up to the peduncle and head.

A final visit was made on August 11 when the crop was being cut. Samples consisting of small sheaves containing several hundred plants were taken at this time. The healthy plants were estimated to be 90% mature with the kernels in the firm dough stage. The straws revealed only a trace of rust. The threshed grain from fifty heads gave a yield of 33.00 grams, weighed 61.2 lb. per bushel by the method of Aamodt and Torrie (1), and graded a poor No. 1, on account of some green kernels. The diseased specimens were similarly treated. The plants were quite green and the kernels were in the late milk or early dough. Rust was estimated at 35 to 40%. The yield from fifty heads was 24.95 grams, weighed 57.2 lb. per bushel, and graded a good No. 4. The sample was degraded on account of shrivelled and green kernels.

It is of course realized that the data just recorded from a single field are merely indicative and are insufficient to afford conclusive proof. At the same time, they suggest what has been the experience of many farmers

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from time to time during the last 20 years, and what was realized by pathologists, namely, that had it not been for the delay in maturity brought about by the root rot, the amount of rust damage would have been negligible and the grain of good quality.

Simmonds and co-workers (2, p. 698) have shown that wheat plants affected with browning root rot may yield only 20% of healthy plants. It is also commonly recognized that rust may reduce the yield by as much as 100%. It is thus seen that the question of how much of the injury recorded above, as reflected in lower weight per bushel and lower grade, is due to browning root rot and how much to rust, is not easily answered and requires further investigation.

When one considers the prevalence of this root rot which is always more severe on the fallow crop, its contribution towards the accumulated damage caused by stem rust and frost is a matter of considerable economic importance. This phase of root diseases, wherein root infections render the plants more liable to subsequent injury by other parasites, or influence the course of later troubles, such as frost, needs to be more generally realized and given further study.

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NOTE ON THE USE OF APPLES IN BREAD BAKING[1]

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Recently a few bakeries in the apple-growing districts of the western United States and at least one bakery in British Columbia have been producing bread containing apples. This laboratory was asked to examine the utility of this practice. A complete investigation of the problem would require a long series of experiments with different flours, different baking formulas and procedures, and different varieties of apples. However, by using a lean formula, it is possible to ascertain whether any marked effect on the quality of the bread is to be expected. The results of the single experiment conducted were so clear-cut that their publication may be of interest.

A commercial baker's patent flour was baked using 100 grams of flour and the simple formula[3] with the addition of apples in three forms and each of these in four different proportions:

Series I. Apple sauce—Apples cooked with a minimum addition of water and boiled until all of the added water and part of the natural water were driven off. The amounts used were 5g, 10g, 15g and 25g, corresponding approximately to 1g, 2g, 3g, and 5g of dry matter. The weight of flour used and the amount of water added in making the dough were reduced accordingly.

Series II. The juice was partially pressed from raw sliced apples in a hydraulic press and the pomace was added to the dough in the same proportions as in Series I, and corresponding adjustments were made in the other dough constituents.

Series III. The juice obtained in the above pressing was added at the rate of 5cc., 10cc., 15cc., and 20cc. with corresponding reduction in the amount of added water.

The loaf volumes obtained from duplicate loaves are given in Table 1.

It will be noticed that all the loaves to which apple was added were larger than the control and that both forms of raw apple gave larger loaves than the cooked apple. There is no marked difference in the size between the loaves to which sauce was added although the tendency is upward with increasing dosage. With the pomace there is some indication that the maximum is reached with the addition of 10 or 15 grams. The juice gave a marked increase in response with increasing dosage.

One loaf from each pair of duplicates was scored immediately after baking and the other stood in a covered tin over night. Series II and III compared well with the control in shape of loaf, while the loaves of Series I were a little flatter and a trifle less bold in appearance. The colour of the crust was darker in Series I and III than in the control but while the loaves

[1] Published as Paper No. 000 of the Associate Committee on Grain Research, National Research Council and Dominion Department of Agriculture.

[2] Cereal Chemist.

[3] Similar to the A.A.C.C. "basic" formula. Cereal Chem. 11 : 363-367. 1934.

TABLE 1.—EFFECT OF THE ADDITION OF APPLES IN VARIOUS FORMS ON LOAF VOLUME

Sample		Loaf volume, cc.
Control (no apple)		51
Series I. Apple sauce	5g.	556
	10g.	560
	15g.	572
	25g.	576
Series II. Pomace	5g.	576
	10g.	605
	15g.	606
	25g.	580
Series III. Juice	5cc.	598
	10cc.	623
	15cc.	621
	20cc.	650

of Series III were bright and attractive, Series I tended to be dull and somewhat darker. The crust colour of all series became progressively darker with increasing dosage. The colour of the crumb in Series I and II became darker with increasing dosage with the loaves in Series I being darker than the corresponding loaves in Series II, and all loaves being darker than the control. Series III, on the other hand, gave loaves that were whiter than the control with little difference between the different dosages. The flavour changed progressively in all series but was least pronounced in Series III. In all loaves the flavour was pleasant, and toast made from either fresh or stale loaves was quite palatable.

When the set of loaves which were stored over-night was examined it was apparent that all the loaves containing apple had staled less than the control. They were moister and had maintained their flavour better. Series III kept particularly well considering the leanness of the formula.

It would seem that there is a possibility of producing very attractive specialty bread by the addition of apples. The fruit used in this experiment had evidently been in storage for some time and was not particularly palatable when eaten raw. Had better fruit been available, the results might have been even more favourable. The rather unattractive colour of the crumb with some of the higher dosages of sauce and pomace can be attributed partly to the darkening of the pulp on standing, which could be prevented in commercial practice. The increase in size of the loaves, which is all the more striking in view of the reduction of the quantity of flour to compensate for the apple dry matter added, is probably partially accounted for by the extra sugar added and perhaps by the presence of ascorbic acid, but it is reasonable to assume that enzyme action was also partly responsible. The pomace was probably lower in sugar content than the sauce and yet gave larger loaves; this could be explained by the destruction of the enzymes on boiling. Furthermore, the fact that the loaves to which the juice was added were whiter than the control can only be explained by assuming the presence of an active oxidizing enzyme, since the juice itself was highly colored and without some such action should have produced darker loaves. The increase in volume was not sufficient to account for the improvement in colour.

ROOTSTOCK AND SCION RELATIONSHIP IN APPLE TREES[1]

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INTRODUCTION

Fruit trees, and apples in particular, are usually composed of two genetically distinct parts: the root-system developed from the rootstock, and the stem or branch system, grafted upon the rootstock, both functioning together as a single living organic unit. They differ in this respect from most other economic plants which are produced either from cuttings or from seeds, so that the root and shoot systems are of the same genetic origin and constitution. Apple rootstocks may be raised either from seeds, in which case the stocks are of miscellaneous genetic origin, or they may be raised by a vegetative method such as layering, in which case stocks of uniform genetic composition are obtained. In practice there is a range of these vegetatively raised rootstocks each with its own special characteristics.

The choice of a rootstock is governed by the aims of the tree propagator. In the case of standard trees for planting in grass orchards, the rootstock must of necessity be vigorous and impart longevity to the scion variety. Until recently seedlings have been regarded as the most suitable for this work, but certain of the vegetatively raised rootstocks are now shown to possess vigour. Whether the trees raised upon these latter rootstocks will also possess longevity must await the verdict of time. For our present purpose it is sufficient to realize that the seedling rootstocks are generally regarded as "vigorous" and that they are of non-uniform genetic origin, and furthermore that certain vegetatively raised rootstocks of uniform genetic origin are also vigorous. Within the range of vegetatively raised rootstocks there are some which produce trees of medium vigour and others which are associated with extreme dwarfing and precocity. In practice, therefore, the propagator chooses a rootstock that will give him a tree with the desired degree of vigour and precocity.

It will be realized at once that the apple tree presents a number of complex problems. What, in fact, is the nature of the so-called rootstock influence?. Does it depend upon the ability of a root system to absorb substances from the soil or upon the ability of the stem to transmit these substances or upon some combination of both? The object of the present investigation is to study the above problem in material specially prepared for the purpose.

REVIEW OF LITERATURE

Rootstock and scion relationship has been the subject of considerable investigation both in England and America for many years now, but has been particularly active since the end of the Great War in 1918. The literature of the subject has now assumed considerable proportions, so large

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in fact that a general review is out of the question. Owing to the fact that certain phases of the work present less formidable difficulties of manipulation and technique, these have received more attention than the others. The effect of the rootstock upon the growth and cropping of the scion variety has been studied in very great detail by the workers at East Malling, and their reports form a most important contribution to our knowledge of the subject (3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 18, 19, 20, 26). Other workers, notably Swarbrick and Roberts (15, 16, 17, 21, 22, 23) have emphasized the importance of an influence of the scion upon the morphology and amount of root development. At present, controversy ranges about the relative importance of these two influences, since the accumulated evidence of the last 10 years shows clearly that the problem is complex and that there are well defined reciprocal influences of scion and rootstock. The fundamental problem that confronts us is, how does a rootstock influence the growth and cropping of a scion, and on the other hand how does a scion variety modify and determine root morphology?

Swarbrick and Roberts (23) noted that the stem portion of the fruit tree in some cases dominated root development to the extent of eliminating the characteristic rootstock effect. They further observed that high budded trees did not have the same dominance of scion over miscellaneous seedling rootstock as was evident in root-grafted trees. Swarbrick (21) pointed out that if the rootstock and scion are separated by a piece of stem other than that of the scion, then the root character may be but little influenced by the top scion variety. He also stated that the interpolated stem-piece markedly influenced root character itself. On the basis of these observations, Swarbrick reasoned that the relative uniformity of trees worked upon vegetatively raised rootstocks may be largely explained by the use of uniform intermediate stem-pieces which such stocks have in contrast to the variable intermediate stems of the miscellaneous seedling rootstocks.

Knight (12) and Grubb (2) working quite independent of each other at East Malling show that a piece of stem 6 inches long inserted between scion and rootstock, a process known as "double-working", had a marked influence upon the growth and the behaviour of the scion variety. Knight (13) however, regarded the actual root system as being more important than the stock-stem in determining scion performance. Roberts (15,16, 17) showed that when two varieties (Wealthy and Whitney) which are known to have different root types, were double-worked with a common stem-piece—East Malling No. IX—the root types were similar, illustrating the marked effect of the stem portion. These experiments showed that as little as one inch of "dominant" stem pieces may prevent the scion influence from being exhibited upon the roots. On the other hand some stocks, such as East Malling No. I, permitted to a greater or less degree the passage of scion influence. Roberts classified such rootstocks as "neutral" and suggests that the so-called vigorous stocks are in actual fact merely "neutral". Hatton (7) in discussing the "build up" of a fruit tree states that, "the insertion of an intermediate piece of stock-stem betwixt a uniform rootstock and the ultimate scion does have an effect, especially marked in the case of pears, upon the behaviour (vigour, fruit bud formation, etc.,) of the ultimate scion."

The recent work in America of Tukey and Brase (24) on the influence of the scion and intermediate stem-piece upon the character and development of roots of young apple trees has shown that in some cases the scion variety has a predominating effect upon the stock while in others it is the intermediate stem-piece, as in the use of a stem-piece of dwarfing stock. Their experiments confirm the findings of Swarbrick and Roberts regarding the influence of the top scion upon the growth and character of the rootstock. These workers point out that the actual perfection of the union is obviously a most important consideration and conclude that in some varieties there appears to be a possibility of incompatibility between the scion and stock.

It seems, therefore, from the data at present available in the literature on rootstock and scion relationship that no one part dominates the entire tree. The rootstock may influence the scion at one time, the intermediate stem-piece at another, and the top scion still another. The literature, however, throws little light on the fundamental aspects of the rootstock and scion effects, and does not evaluate the precise function of the different parts of the tree.

MATERIAL AND METHODS

The present investigation is designed to study the influence of the intermediate stem-piece upon the vigour and precocity of a scion together with its effect upon growth and character of a rootstock. No clonal vegetatively raised rootstocks have been included in this experiment so that the differences in growth, tree size, weight and precocity that are recorded herein are the direct result of the stem-pieces that have been inserted between the absorbing root system and the scion variety.

The material used is divided into three groups each having a common "build up": (1) Bramley Seedling on E. M. No. IX on French Crab; (2) Bramley Seedling on E. M. No. II on French Crab; (3) Bramley Seedling on E. M. No. XIII on French Crab. All trees, therefore, are double-worked; *i.e.*, situated between the scion variety proper, Bramley Seedling, and the root system, Miscellaneous Seedling French Crab, there is a clonal intermediate stem-piece, nine niches long of either E. M. No. IX, E. M. No. II, or E. M. No. XIII, which is different from both. The trees under observation have a common absorbing root system, namely, miscellaneous seedlings of French origin. Genetically, the root systems differ from one another but by common consent they may be regarded as free growing rootstocks capable of giving rise to strong growing vigorous trees.

Numerical records of tree height, spread and girth, together with total amount of shoot growth produced during the growing season, have been obtained. Weights have been taken of the componant parts, *i.e.*, shoot growth, main branches, trunk, intermediate stem-piece, coarse and fine roots, of the 6 trees of each group excavated during the course of the investigation. The principal measurements and weights taken on the lifted trees have been devised so as to express qualitative characters as quantitative differences in size and weight. Field notes upon the general habits of the trees have been recorded. The numerical data have been subjected to statistical treatment.

RESULTS

It is impossible in a paper of this nature to present more than a discussion of the results obtained. The most outstanding feature revealed

by the data as a whole is the way in which trees with intermediates of E. M. No. IX differ in almost every respect from trees with intermediates of E. M. No. II or E. M. No. XIII. The trees with intermediates of E. M. No. II and E. M. No. XIII, however, are almost identical in size and weight, but they do exhibit "qualitative" differences which serve to distinguish them from each other.

This general statement may be substantiated by brief reference to a few of the numerical data obtained. In the matter of tree size as indicated by head volume, trees with intermediates of M IX have a head volume of only 7.4 cubic metres, whereas in trees with intermediates of M II and M XIII the figure is 12.15 cubic metres, which is almost double. In total tree weight, including the root system, the average of 6 trees each with intermediates of M IX, II and XIII, is 16.4, 24.7, and 27.7 kilos respectively. The trees with M IX as intermediates are therefore only a little more than half as heavy as with intermediates of M XIII. Finally, in the matter of precocity expressed as the number of flower trusses produced per metre of 1935 shoot growth, the differences are even more outstanding. Trees with intermediates of M IX are extremely precocious having produced an average of 2.6 blossom trusses per metre whereas the average is only 0.4 for trees with intermediates of M II and M XIII.

The above evidence establishes beyond any doubt the fact that when a piece of M IX stem is inserted between a vigorous root system and a scion variety, the growth of both scion and root system is seriously reduced in amount as compared with trees with intermediates of M II or M XIII, and the precocity of the trees is also affected to a marked extent. Too much emphasis cannot be placed at this stage upon the fact that these differences have been produced by a nine inch long stem-piece inserted between the root system and the scion variety.

It has been found that the three rootstock stem-pieces used in this experiment exhibit marked differences in their radial development. The cross sectional area of M II, for example, is less than that of M IX notwithstanding the fact that the trees with M II as the intermediate are twice as big as those with intermediates of M IX. It is an extremely interesting fact that M II, when used as an intermediate, appears as a constriction in an otherwise normally well developed main stem. Radial development of the intermediate in this case does not appear to be a necessary part of the production of normal development in the tree as a whole. The intermediate stem-pieces of M IX are in marked contrast to those of M II; in cross sectional area the intermediate is greater than that of the scion stem except where the latter is "swollen" just above its union with the M IX piece. The growth and development of the trees, with M IX as their intermediate, is retarded despite the abnormal radial development of the intermediate. It would appear, therefore, that the amount of radial development of the rootstock does not provide an immediate clue to its effect upon vigour and tree size.

Owing largely to an almost complete lack of the necessary anatomical and physiological data, an adequate discussion of the above observations cannot even be attempted but the following points can be made at this stage. The question naturally arises, wherein does this influence reside or what function in the stem determines it? Two possibilities are presented.

In the first place attention is called to the "quality" or appearance of the actual unions in the three groups of trees under discussion. It should be recalled that there are two unions in each stem, *viz.*, the "upper" where the intermediate stem-piece meets the scion and the "lower" where it meets the stem of the absorbing root system. Considering just the case of the trees with intermediates of M XIII, it is found that both upper and lower unions present no observable abnormality. The stem in the region of the unions appears normal in every way, and, in fact, it is often almost impossible to determine the exact location of the unions. The growth of these trees both as regards top and roots is normal and vigorous. In the case of trees with intermediates of M II, the intermediate stem-piece is clearly defined as a restricted portion of the main stem and both upper and lower unions are clearly defined. The upper and lower unions, however, do not present the same appearance although both are smooth and mechanically strong. The upper union shows a marked tendency to enlarge and the tissues of the scion stem appear to "flow" downwards over the smaller intermediate stem. At the lower union the smaller intermediate stem-piece meets a much larger rootstock-stem. This latter has been stimulated into development through the use of intermediate stems of M II. It is clear, therefore, that when M II is used as an intermediate stem-piece, between Bramley Seedling and miscellaneous seedling rootstocks, it makes a perfect union and permits the free development of both. Clearly, therefore, an equal radial development of both scion and intermediate is not essential to the free development of the tree as a whole. It should be noted in this connection that the unions are mechanically strong since it has been found impossible to break them except by a shattering or splintering of the whole of the tissues in a longitudinal direction. There is apparently complete xylem continuity across these unions despite the marked differences in the cross sectional area exhibited by scion, intermediate and rootstock.

In the case of M IX, the unions it makes with scion and rootstock stem are different from each other and show certain differences from those made by M II or M XIII. In the first place, the piece of M IX intermediate stem is larger in diameter than either the scion-stem or rootstock stem. The upper union in this case, *i.e.*, the union between scion and intermediate, is marked by a swelling of the tissues of both scion and intermediate. In contrast to the smooth appearance of the similar union in the case of M II, that of M IX is rough and uneven. There are unmistakable signs of a discontinuity of the tissues. It is comparatively easy to break the tree across at this union and when so broken it is found that the xylem tissues have never been really knit together. The union presents a conglomeration of cells and tissues lying in all directions. It is indeed surprising that the trees have managed to grow as well as they have considering the discontinuous nature of this union. It would appear, therefore, that at present there is no reasonable explanation of the causes of rootstock influence. Both structural and physiological factors are involved and the elucidation of these must be the next step in the progress of this investigation.

The effects discussed so far have a quantitative character and the results are capable of statistical analysis. It should be noted, however,

that the use of these intermediate stem-pieces has also produced effects that are of a non-measurable or "qualitative" character. These effects have reference to such factors as leaf poise, general habit of branching, the coloration of the leaves, particularly just prior to leaf fall, and the time of autumn defoliation. From the present series of experiments there is no means of determining how far similar influences may be induced in a scion by the roots of these rootstocks when precautions are taken to eliminate any of the rootstock stem. Preliminary studies of this aspect of the problem have already been made by Hatton and his colleagues at East Malling (7, 8, 25) but the matter is so important that it needs further work in order to establish the points at issue.

The discussion so far has concerned the effect which the intermediate stem-pieces have upon the above-ground parts of the tree, but the data also show that they affect the root system in almost the same way. The effect is upon both the amount of root as measured by root spread or by total weight and upon morphology. The trees with intermediates of M IX are shown to have root systems that are only half as heavy as those with intermediates of M XIII. It is important to notice that the effect of M IX when used as an intermediate stem-piece is to dwarf both top and root development, although not to the same extent. The effect upon root development is even greater than it is upon the above-ground parts of the tree. The more interesting point, however, is that although the amount of root development is determined by the intermediate stem-piece there is no apparent effect upon the proportion of coarse roots to fibre. In all three groups of trees the proportion of coarse roots to fibre is the same. It should be remembered, however, that in this experiment the division between coarse and fibre is purely arbitrary and it is quite possible that the basis of division does not allow of the expression of any differences that may exist.

As in the case of the top growth, the effect of the intermediate stem-piece upon root development is shown in qualitative as well as quantitative differences. In the absence of an accepted terminology and root morphology these differences are difficult to describe. They were, however, clearly visible in the material as it was lifted.

The evidence that the intermediate stem pieces as used in this experiment have profoundly changed and determined the physiological relationship of the top and root systems is unmistakable. The top to root ratio, using total weight in each case, is 3 : 5 and 3 : 9 for the trees with intermediates of M II and M XIII respectively, but in trees with intermediates of M IX, the ratio is increased to 5:2. This difference is considerable and is an important index of an effect upon physiological relationship between the root and shoot systems. The difference in ratio between the trees on M II or M XIII and M IX is important since Vyvyan (25) has suggested that in his material, which was worked in the normal manner on to complete rootstocks, the trees have a constant stem to root ratio irrespective of the rootstock. He suggests, in fact, that the stem to root ratio of a tree is a physiological constant within a variety not subject to variation even by rootstock. The data obtained during the course of the present investigation has been obtained from trees of a different "build up" from those used by Vyvyan. In the present case the trees have only intermediate

stem-pieces of the rootstocks inserted in the main stem of the tree but the evidence suggests that the top to scion ratio is established at different levels depending upon the intermediate stem-piece. A preliminary examination of the data shows that this ratio has been affected because in trees with intermediates of M IX, the root system is dwarfed more than the top. This in itself is an important observation, and, furthermore, it opens up a completely new field of investigation, namely the importance of the stem to root ratio in precocity, fruitfulness, fruit quality, etc. The possibility that the stem to root ratio of a tree may be stabilized at different levels through the influence of a rootstock or an intermediate stem-piece is a consideration of both theoretical and practical importance.

SUMMARY

The present contribution in the literature of rootstock and scion relationship supplies some much needed information on a particular aspect of the problem, *viz.* the relative importance of the stock stem-piece in the production of so-called rootstock influences. Emphasis is placed in this study upon the part played by the stem rather than that of the absorbing root system. The practical value to be obtained from the double-working of a fruit tree has been appreciated for many years and is, in fact, embodied in some of the current practices both in Europe and America. In certain parts of central Europe and America winter hardiness is a factor of economic importance and since the damage by frost is frequently confined to the stem regions of the tree, winter hardy trees are produced by a double-working method. The resistant stem or trunk piece is built up into the tree between the root system and the top scion variety. Work upon this phase of the problem has already been published and described by Filewicz (1). In the more southern states of America where the disease of "collar rot" is particularly troublesome, the common nursery practice is to double-work using a non-susceptible intermediate piece. Only in this way can trees of varieties like Grimes Golden be grown in these regions. Furthermore, it is well known that certain varieties of the cultivated pear will not "take" directly on the quince rootstock but that they will make excellent growth if they are suitably "double-worked" using a compatible intermediate stem-piece. Hatton and Grubb (9, 2) have published their observations upon this phase of the problem. The practical utility of double-working is clearly appreciated and forms a part of an established custom but as yet there is very little exact knowledge as to the cause of the above phenomena.

In the main the present findings as recorded herein, confirm and corroborate those of Tukey and Brase (24), particularly as regards the effects produced by M IX when it is used as an intermediate stem-piece. Of the causal factors that produce in a scion the so-called rootstock influence there is but little information available. Tukey and Brase suggest that it may be causally connected with the "nature of the union". At first sight this appears to be a possible suggestion but upon close examination it does not meet all the known facts of the case. Considering only the cause of the incompatible union made between the Bramley scion and the intermediate piece of M IX, the "nature" of the union is a possible suggestion since the union is obviously very abnormal. It is here suggested that factors of a fundamental physiological nature are responsible

for the so-called rootstock influence because it is shown in the present paper that it is produced by an intermediate stem-piece of the rootstock. Furthermore, the evidence of Tukey and Brase that reciprocal grafts of two varieties do not always show the same growth performance suggests that something more than the nature of the union is involved because in this case the unions are between the same two varieties in two different trees. Thus it is shown that using a common absorbing root system, Winesap when double-worked onto Northern Spy makes an excellent tree but when Northern Spy is double-worked onto Winesap the tree is a complete failure and usually dies within a few years. This surely suggests something more than the nature of the unions because in both cases the union is between Winesap and Northern Spy. The only difference in this case is the polar position of the scion varieties. It looks as though one of these two varieties possesses some marked growth character which prevents its being used as an intermediate stem-piece. In fact, it is clear that in this case Winesap stem-pieces behave as "dwarfing rootstock" to the scion variety Northern Spy but that the latter behaves as a vigorous rootstock to the scion variety Winesap.

The behaviour of M II when used as an intermediate stem-piece presents further evidence in support of the suggestion that the influence is related to fundamental physiological growth factors, of which the nature of the union is also a phenomena. It will be remembered that M II facilitates the rapid and vigorous development of both scion and rootstock yet itself develops much less radial growth than either. The unions in this case are clearly defined but are demonstrably mechanically strong and in this respect contrast sharply with the unions of which M IX forms a part. It is impossible to offer any direct proof at the present time but the evidence obtained during this study and that presented by Tukey and Brase suggests that the influence may be closely related to such fundamental stem function as translocation. This may be directly controlled by the amount of the phloem or its periodicity of development or it may be related to "specific varietal characters" or differences in the translocation of either raw or elaborated materials.

It is quite clear that the physiological problems involved in such a study of rootstock and scion relationship as here presented are of a complex structure. In fact, it could hardly be otherwise since both scion and rootstock are so very dependent upon each other for the means of subsistence. The evidence advanced in this paper suggests that in some cases it may be the "nature of the union", as in the case of M IX, which gives the characteristic effect. But from a fundamental standpoint the nature of the union is dependent upon the co-ordination of several functions of the stem tissues and also upon the sheer mechanical problem of obtaining xylem and phloem continuity in tissues which may or may not have the same cell size, shape and structure. There is evidence to suggest that the latter considerations may be very important. Furthermore, the normal periodicity in tissue development and the whole problem of translocation are involved.

The present series of experiments clearly establishes one point of both fundamental and practical importance, namely, that the so-called rootstock effects upon the growth and precocity of a scion can be produced, in the

case of the three rootstocks M IX, M II and M XIII, without the aid of their respective root systems by inserting stem-pieces of these varieties between an absorbing root system of accepted vigour and the scion variety. This effect may not be solely confined to stem-pieces but can be produced by them. This narrows down the field of investigation very considerably and makes a better understanding of the functions of stems all the more urgent.

From the practical point of view it opens up certain possibilities of considerable economic importance. The vegetatively raised rootstocks are comparatively expensive to produce owing to the methods of layering or stooling which must be adopted. If it should be ultimately established that the effects of a rootstock can be produced for the most part by a double-working process, tree production can be made less expensive particularly in the case of M IX. Furthermore, a double-working process allows much greater elasticity in the "build-up" of trees. So far only varieties that will "root" when subjected to layering methods can be employed as rootstocks, but it is evident that provided the absorbing root system is suited to the climate or soil there is an almost infinite range of possible "rootstock effects" to be obtained by using different intermediate stem-pieces. The fact that reciprocal graft unions do not behave the same way increases this range enormously. At the moment these are only possibilities but even a brief survey of the problems of producing cold-resistant trees, and trees resistant to Collar Rot and other stem and root problems, shows how wide the possible range is of their application. The practical experience of a former generation of fruit growers who have insisted that certain varieties could not be successfully top-worked onto other sorts is easily understandable in the light of the work of Tukey and Brase and that presented in the present paper.

Future experiments on the rootstock and scion relationship must clearly recognize the importance of the stem-piece in any possible rootstock influence upon the scion or of the effect of the scion upon the morphology and development of the root system, and the future work must of necessity tend to be more and more in the field of applied plant physiology.

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NOTES ON THE STRAWBERRY ROOT APHID AND THE EFFECTS OF ITS FEEDING PUNCTURES ON STRAWBERRY ROOTS[1]

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INTRODUCTION

In September, 1936, roots and crowns of strawberry plants growing in experimental plots at St. Catharines, Ontario, were found to be heavily infested with the strawberry root louse, *Aphis forbesi* Weed[3]. The discovery of the insects made it possible to account for the marked difference in vigour of plants which had become increasingly evident in different plots as the season had progressed and which previously could not be correlated either with soil treatments prior to planting or with any other causal agency. Examination of the roots and crowns of plants from the various plots showed clearly that mortality and lack of vigour of plants were closely correlated with the degree of infestation by the insect. Further, it was noted that, in many cases, roots heavily colonized by the insects were also frequently infected with root rot. In such cases it was sometimes difficult to decide which of the two agencies might have been primarily responsible for the degeneration of the plants. Thus, the question arose as to whether or not in certain instances at least, aphids might be an additional factor in the already very complex root-rot situation (2). Embodied in the present paper are results of an investigation undertaken in an attempt to determine the possible rôle of this insect in the pathology of the strawberry. These studies, by no means exhaustive, have yielded certain information relative to the feeding habits of the insect and to its distribution in Ontario. The former is of interest because relatively little is known of the interrelations of subterranean aphids and their host plants, the latter because *Aphis forbesi* Weed has not been reported heretofore as being of economic importance in Ontario.

DISTRIBUTION AND ECONOMIC IMPORTANCE

According to Massee (6), *Aphis forbesi* Weed is one of the seven species of aphids which up to 1933 had been recorded on cultivated strawberries by investigators in France, Italy, Germany and the United States. Further references to the occurrence of *A. forbesi* in Italy and Germany have not been consulted. In France, Pussard (7) in 1931 reported the presence of the insect in two strawberry-growing districts and suggested the advisability of investigating not only its possible wider distribution, but also the rôle it might play in the recent serious decline of the strawberry in that country. Being indigenous to eastern North America (5), and on various occasions having assumed importance as a limiting factor in straw-

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[3] For confirmation of the identity of the insect and for other valuable information relative to the present studies, the writer is indebted to Mr. W. A. Ross, Dominion Entomological Laboratory, Vineland Station, Ontario.

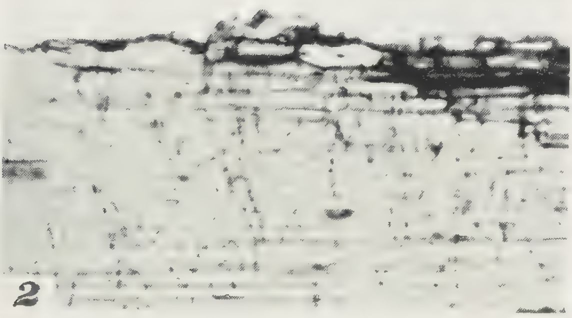
berry production, the insect has commanded considerable attention in the United States. According to Weed (14) who in 1889 reported a general distribution of the insect throughout Ohio, injury by the pest had been first noted in the United States in southern Illinois in 1882. In a comprehensive report in 1900, which included an account of life-history studies and results of control experiments, Sanderson (10) stated that "the most serious pest with which the strawberry growers of Delaware have had to contend for the past ten years is the strawberry root louse." At the time of this report the insect had ruined plantations not only in Delaware, but in Maryland as well. Further, it had been reported from New Jersey (12) and from Florida, and apparently was being spread even more widely by means of nursery stock from infested regions. By 1921, according to Sanderson and Peairs (11) the aphid was reported as injurious to the strawberry in most of the states east of the Rocky Mountains. These writers generalize as follows ". . . . . injury is most serious on light, sandy soils and the pest rarely becomes troublesome on heavier soils. Injury also is more or less periodic, the aphids almost disappearing after doing some injury for two or three years." In connection with investigations carried out in Tennessee, Marcovitch (5) in 1925 acquired information which indicated that in Iowa, Illinois, Ohio, New Jersey, Delaware, North Carolina, Georgia, Florida, Louisiana, Mississippi and Arkansas, the insect was no longer as important economically as apparently it had been two or three decades earlier. At that time Maryland alone reported serious injury, especially in plantations located on light, sandy soil. That the importance of the insect as a potential threat to strawberries cannot be discounted too greatly, however, is indicated by Reed (8) who reported in 1933 that "in North Carolina attention had been given since 1929 to strawberry injury from aphids and that the aphids are responsible for considerable loss of strawberry plants in that region." The only aphid which is specifically mentioned in the above report is *Aphis forbesi* Weed. In Ontario, so far as is known, only casual reference (9) to the occurrence of the insect has ever been made.

According to the latest authorities consulted (6, 8), *Aphis forbesi* Weed has never been found living on any plant other than the wild and cultivated strawberry, and invariably the insect is attended by ants, by which young aphids, after feeding on young leaves in the spring, are carried down and placed on the roots of plants.

GENERAL OBSERVATIONS

The experimental block where the aphids were first found, comprising about one-third of an acre of ground, was divided into a number of smaller constituent plots arranged in four long adjacent and parallel rows. One end of the block was on higher ground, the other on lower, with a gradual slope intervening. The soil at the higher end is of the consistency of garden loam, but approaching the slope and on the slope itself, it shades into a light, sandy loam. On the lower level, where surface water is retained much later in the spring, the soil is almost a clay loam. After various treatments of the soil in the different plots (in connection with certain phases of root-rot investigations), strawberry plants, variety Premier, were planted late in April, 1936. Probably soon after the plants were set

1



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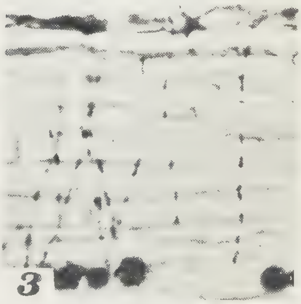
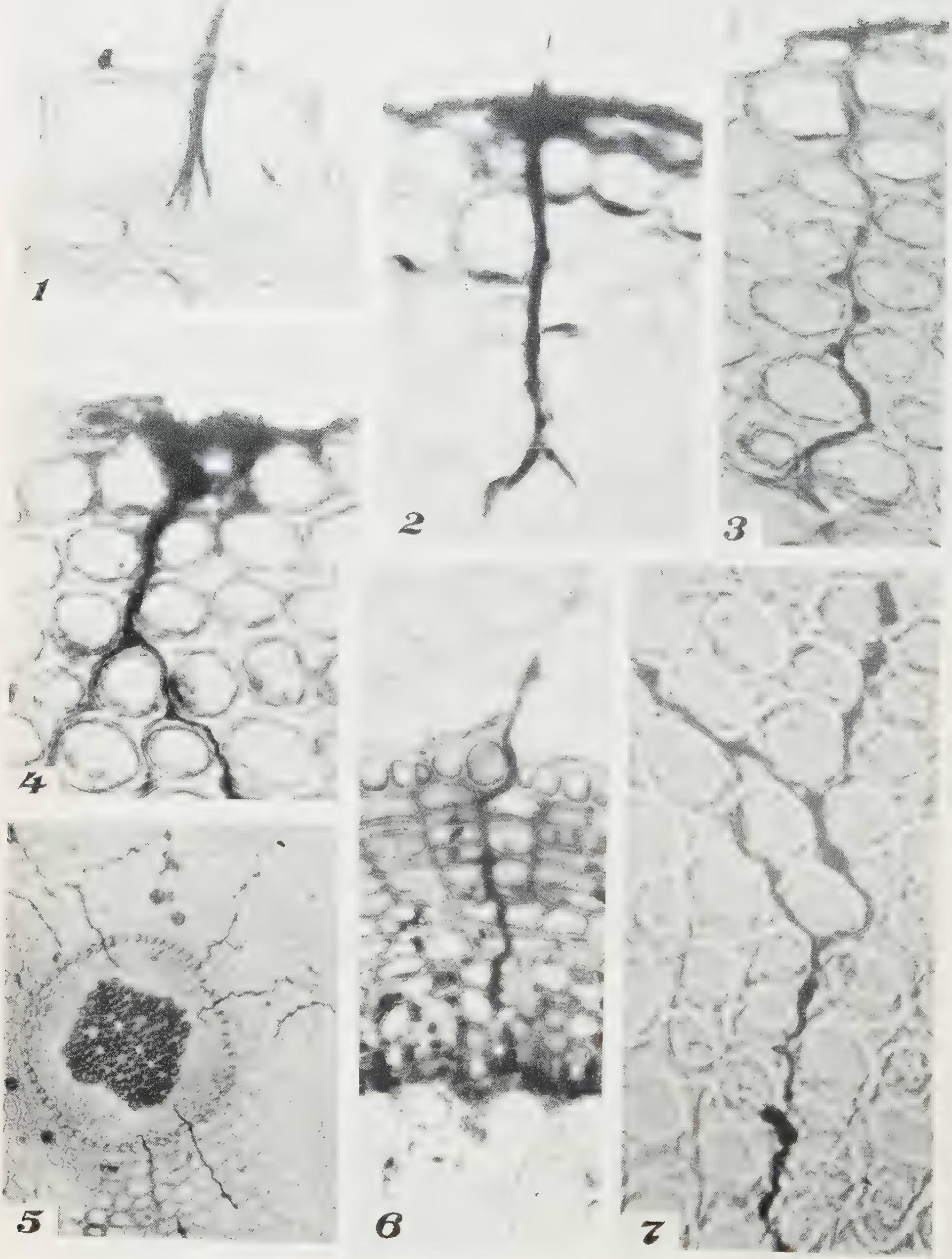


3

FIGURE 1. Roots of strawberry (most of laterals removed) infested by the root aphid. Note extent of aphid clusters, $\times 1\frac{1}{3}$. FIGURES 2 AND 3. Radial sections at points of heavy infestation, showing numerous feeding punctures in cortical tissue. Note "beaded" effect due to accumulation of materials constituting the setal sheath in the intercellular spaces, $\times 95$. In upper right of Figure 2 excessive suberization of outer cells of cortex is due primarily to infection by fungi which are not visible at this magnification.



Photomicrographs from cross-sections of roots of different ages, showing feeding punctures of aphids in relation to root tissues. FIGURE 1. Tip of stylet penetrating between epidermal cells of younger root, ×450. FIGURE 2. Stylet in cortical tissues of older root, ×300. FIGURES 3, 4 AND 7. Stylet paths through cortical tissues, ×300. In FIGURES 3 AND 7 (younger roots) note accumulation of materials constituting setal sheath in intercellular spaces, absence of injury to cells contiguous to feeding puncture and intercellular mode of penetration. In FIGURE 4. (older root) note how tissue has been probed by stylet. FIGURES 5 AND 6. Stylets having penetrated between the cells of the endodermis, have continued through the pericycle to the region of the phloem, FIGURE 5, ×95; FIGURE 6, ×300.

out they were colonized by the aphids, but it was not until September that their presence was discovered on plants in one outside row of plots.

Seasonal Activity

As early as May 4, 1937, nymphs were found not only on the petioles and under surface of young leaves unfolding from the crown, but also about the crown itself and on roots ramifying near the surface of the soil. Towards the middle of May the activity of ants about the crowns of older plants growing in the lighter soil suggested the presence of aphids. Upon exposing the roots of such plants *in situ* young and mature stem-mothers were found in abundance (Plate I, Figure 1), on both earlier- and later-formed roots and rootlets. Thus, early in the growing season while the soil was still cool and retained an abundance of moisture, aphids became a factor demanding consideration in the pathology of the strawberry. Progressively the aphids spread from plot to plot at the same time increasing in numbers on plants colonized earlier in the growing season. A peak was reached toward the latter part of July at which time injury was so severe in many plots as to mask any effects, beneficial or otherwise, that might have accrued from the soil treatments prior to planting. During August, September and October the insects were found in gradually decreasing numbers and more usually on older plants. Final observations for the season, in mid-November, were of unusual interest because of the fact that the small, shiny, black, oval-shaped eggs about one thirty-fifth of an inch long were found not only on the petioles and along the veins of the central cluster of green leaves where other observers have reported their presence, but also *on roots growing at a depth of several inches in the soil*, in which location they do not appear to have been reported heretofore.

The possibility of eggs hatching at a depth of even a few inches in the soil at once introduces new difficulties in regard to effective methods of control. Heretofore, control has centred mostly around the use of insecticides applied to the surface of the soil about the plants in the spring in an attempt to destroy the recently-hatched stem-mothers before they can be carried from the aerial parts of plants to the roots by ants. If the subterranean eggs hatch *in situ*, then there may be young insects which are protected from the lethal effects of the insecticide by a protective barrier of soil. Further, it would seem that not all the insects that may be present on the roots of plants early in the spring have been carried there by ants, despite views to the contrary expressed by earlier investigators.

Effect on the Plant

In regard to symptomatology, general lack of vigour is the outstanding characteristic of plants infested by the root louse. Some plants very heavily colonized by the insect die in a relatively short time, but the majority linger throughout the season in a state of semi-flaccidity just bordering on wilting. In general, young plants escape infestation but as they become older they too are attacked and soon show arrested development and lack of vigour. Loss of vigour is indicated in no better way than by paucity of runner formation. In September, 1936, a count was made of the number of primary runners produced by plants in the row of plots where the aphids had made their appearance. The result of this count,

the percentage of plants attacked by the insect during the peak of infestation in July, and other pertinent data are incorporated in Table 1.

TABLE 1.—INFESTATION BY *A. forbesi* WEED AS AFFECTING RUNNER PRODUCTION AND VIGOUR OF STRAWBERRY PLANTS, VARIETY PREMIER, DURING PERIOD APRIL TO SEPTEMBER, 1936

Plot no.	Condition of plants at final examination			No. primary runners	Percentage infestation by aphids*	Soil type
	Healthy	Weak	Dead			
4	96.4†	3.6	0	155	6	Garden loam (higher ground)
8	82.1	14.3	3.6	156	13	
12	92.8	3.6	3.6	160	20	
Group 1 Averages	90.5	7.1	2.4	157	13	
20	10.7	53.5	35.7	60	100	Light sandy loam
24	67.9	32.1	0	116	80	
28	32.1	39.3	28.6	62	100	
32	78.6	14.3	7.1	127	56	
40	82.1	3.6	14.3	83	66	
Group 2 Averages	54.2	28.6	17.2	89.6	80.4	
60	96.4	3.6	0	163	33	Sandy loam (sloping ground)
68	96.4	0	3.6	208	0	
72	85.6	7.2	7.2	191	0	
Group 3 Averages	92.8	3.6	3.6	187.3	11	
80	71.4	10.7	17.9	89	33	Clay loam (low ground)
84	85.6	10.7	3.7	102	0	
88	57.1	28.6	14.3	61	0	
Group 4 Averages	71.4	16.7	11.9	84	11	

* Calculated from examination of roots of fifty plants of comparable ages from each plot.
† Expressed as percentages of original number of plants set out in each plot.

Reference to Table 1 will show that in plots of Group 1 (4-12, garden loam soil), where the average infestation was only 13%, the average for healthy plants is slightly in excess of 90% and the average for runner production was 157. In plots of Group 2 (20-40, light, sandy loam), where infestation ranged in severity from 56 to 100%, with the high average of 80.4% for the group, the average for healthy plants is reduced to 54.2%, while the averages for weak and dead plants have increased to 28.6 and 17.6%, respectively, as compared with 7.1 and 2.4%, the corresponding figures for Group 1. Correlated with the much more severe infestation in the light, sandy loam is the marked reduction in runner formation, the average for the group being reduced to 89.6 as compared with 157 for the preceding group. In plots 20 and 28 where no plants were found that were free from aphids, the paucity of runner production is striking. Marcovitch (5) in Tennessee did not find such a marked correlation between infestation by *A. forbesi* Weed and reduced runner formation, plants arti-

ficially infested with the aphid having produced an average of 47.6 plants as compared with 49.7 plants produced by controls. In this connection it should be pointed out, however, that in Tennessee the insects remain mostly on the petioles of the leaves and around the crown, only rarely being found on the roots. In plots of Group 3 (60-72, sandy loam), infestation tapers off abruptly, runner production reaches a maximum with an average of 187.3 for the group, and a higher percentage of plants has remained healthy than in any other group of plots. In plots of Group 4 (80-88, clay loam), where aphid infestation was almost negligible there was a marked decline both in vigour of plants and in runner production, the average number of runners being only 84, the lowest for any group of plots, even those in which infestation was most severe. This apparently anomalous situation is explanied by the fact that root rot rather than injury by aphids was the dominant factor in this lower-lying section of the experimental block. Root rot was, in fact, present in all the plots both in 1936 and 1937, but on the sloping and higher ground, plants were not seriously enough affected by this disease alone to show symptoms in their above-ground parts.

Aphid Infestation as Related to Root-rot

Aphids were found scattered either individually or in small groups on main roots or their laterals. Usually, however, the insects were concentrated in clusters covering a surface varying in extent from a few millimetres to several centimetres. An individual root may be attacked anywhere from the tips of its laterals to its point of emergence from the crown. In certain instances it was noted that infested main or lateral roots showed lesions of the type that has been regarded as symptomatic of root rot. The location of the aphid cluster did not necessarily coincide with that of the lesion, but in a number of cases they were close enough together to suggest an association between the two. It appeared as if the aphids having exhausted the food supply at a given point might have moved on to a new location, leaving necrotic and discoloured tissue in the old. Late in October, 1936, sufficient plants were dug from heavily infested plots to permit of selection from roots *in toto*, 100 individual main roots colonized by clusters of aphids. The roots were selected in every case from the new part of the root system, *i.e.*, that formed in the late summer and early autumn. It was considered that selection of roots of this age would eliminate as a possible complicating factor colour changes and other phenomena associated with senescence of root tissue. Small pins were stuck through the roots to mark the limits of the aphid colonies, whereupon the specimens were preserved in formol-acetic-alcohol solution for examination later.

When the insects were carefully brushed from the surface of the roots, it was found that in only 10 cases did aphid clusters coincide with visibly discoloured or necrotic tissue. Of the remaining 90 roots, 47 showed no discoloration or other visible evidence of injury where the aphids had been feeding. However, many of the finer laterals were dead or dying and the roots as a group showed the more or less flaccid condition that follows aphid attack. The absence of visible damage to the roots by *A. forbesi* at the point of feeding, as noted in the present investigations, has been recorded by other workers, Sanderson (10) for example, having written as

follows: "If any poison is injected into the plant by the beaks of the aphids, as in the case of some species, it has no visible effect, as there is no swelling or distortion of the roots . . . ." In addition to clusters of aphids, the remaining 43 roots showed a typical root-rot condition, but since the feeding position of the insects did not coincide with lesions on the roots or with dead or decaying laterals, it was concluded that there was no correlation between the two. Further evidence confirming the conclusion that root rot is quite independent of aphid injury was provided by the fact that the disease was present in plots to which up to that time aphids had not spread.

Distribution in Ontario

During the course of a survey carried out early in the summer of 1937, the root louse was found on the roots and crowns of 1- and 2-year-old plants in 7 of some 50 commercial plantations situated in widely-separated strawberry-growing districts of central southern Ontario. In 5 of the 7 plantations where the aphids were found, the soil was a light to sandy loam; in another it was a fairly heavy loam and in another it was a heavy loam, almost a clay, and was quite moist. Since none of the 7 plantations was entirely free from root rot, it was impossible to evaluate the effect of aphid injury alone, but in no case was infestation by the insect as severe as in the experimental plots at St. Catharines.

Host Range

The roots of weeds and of cultivated plants growing within or in close proximity to the experimental block, as well as the roots of *Fragaria vesca* and *F. virginiana* growing in their native habitat, have been carefully examined during the past two seasons for the presence of the aphids, but to date the insect has not been observed on other than cultivated varieties of the strawberry. Aphids similar in colour to *A. forbesi*, but larger in size were found on the roots of purslane growing in some of the infested plots. These observations are in accord with those of other workers who have investigated this insect, though according to Massee (6) *A. forbesi* Weed has been reported on *F. vesca*.

MICROSCOPIC STUDIES

Material and Methods

Supplementing the observations recorded above, detailed microscopic examination was made of a large number of both infested and non-infested but visibly discoloured and diseased roots collected at successive intervals throughout the period of study. Thus, the specimens examined included not only younger roots in the primary condition, but older ones as well in successive stages of secondary development. When specimens could not be examined immediately, they were preserved in formol-acetic-alcohol solution, which fixing agent was rapid enough in its action to prevent many of the feeding aphids from withdrawing their piercing setae before they were killed. For staining, transverse and longitudinal razor sections of both fresh and preserved roots were boiled for a few moments in lacto-phenol with acid fuchsin added and then mounted in clear lacto-phenol. In microchemical tests for fatty materials, for suberin and for starch, sections of both fresh and preserved specimens were stained with Sudan III and mounted in glycerine in which a small amount of iodine was dissolved.

The latter technique as Mann (4) has already pointed out, gives excellent differentiation especially in the case of the highly specialized polyderm which, consisting as it does, of zones of unsuberized cells containing starch, alternating with single-celled discontinuous cycles of cork cells containing no starch, functions as a combined protective and storage tissue characteristic of the older main roots of the strawberry.

Microscopic Examinations

Prefacing the observations which are recorded below, it may be stated that the Aphididae have a suctorial type of mouth structure similar anatomically to that found in other families of the Homoptera. From the tip of a tubular beak or rostrum which in feeding is closely adpressed to the surface of the host, 4 bristle-like, chitinous setae can be extended to pierce the plant tissue. The setae or stylets form a tube through which a pharyngeal pump sucks material from the plant and also during the process saliva is injected into the plant tissues.

Microscopic examination of sections of roots infested by *A. forbesi* showed many stylets *in situ*, which had penetrated the root tissues to varying depths (Plate II, Figures 1 and 2). In addition, the acid fuchsin had stained what at first was interpreted to be a curious, unbranched "beaded mycelium" (Plate I, Figures 2 and 3) which appeared to penetrate the root mostly at right angles to its long axis and which seemed to be directed consistently toward the vascular cylinder. Soon it was realized, however, that what was being stained was the so-called setal sheath (15, 16) which characterizes the punctures or stylet tracks of homopterous insects. In the case of at least four species of aphids Horsfall (3) has found the setal sheath to be composed of proteid material as well as calcium pectate, the former possibly injected into the plant tissues by the insects, the latter evidently laid down by the plant cells in response to the wound stimulus. As is shown clearly in Plate II, Figures 1 and 3, penetration of the roots by the setae is effected not through but *between* the cells of the epidermis or the hypodermis, as the case may be, depending on the age of the root at the point of attack. In younger roots penetration is not accompanied by any marked increase in the normal degree of suberization of the cells of the hypodermal region, nor is there any evidence of hypertrophy or hyperplasia in the invaded tissues (Plate II, Figures 1 and 3). Thus, the insect causes very little visible evidence of injury, in which respect its feeding on the roots of strawberry is analogous to that of *Myzus persicae* on the stems of potato (13). In older roots suberization of the walls of the cells of the hypodermis and outer cortex is intensified (Plate II, Figures 2 and 4) but to what degree this may be attributed to the feeding of the insect alone is difficult to decide since in many such cases fungous mycelium is also present. The piercing organ passes intercellularly through the cortex, the "beaded" effect referred to above being due to an accumulation of the materials composing the setal sheath in the intercellular spaces (Plate II, Figures 3 and 7). In many cases the stylet has evidently been retracted and after considerable probing between the cells, has been thrust towards its objective along a new path (Plate II, Figures 4 and 7). However, very few, if any, of the cortical cells are tapped for nourishment and most of them contiguous to the path of the stylet remain in a turgid, healthy condition, with their contents unimpaired (Plate II, Figures 3 and 7.)

It might be expected that the endodermis would bar further progress of the piercing organ but even in roots that have reached an age when secondary suberization of the endodermis is complete (approximately 6–7 months) the stylets readily penetrate between the cells of this highly specialized band of tissue, continue intercellularly through the pericycle and finally tap the region of the phloem (Plate II, Figures 5 and 6). In still older roots in which the cortex is undergoing disintegration, the endodermis has disappeared and the former pericyclic region is now occupied by a zone of true cork several cell-layers thick, the stylets still penetrate to the phloem. In the latter tissue, a certain amount of disintegration often seems to have taken place in cells in the more immediate vicinity of the tip of the invading stylet (Plate II, Figure 6). Apart from this possible injury to the phloem, there seems little evidence of disturbances in the various tissues of the root due to toxins or enzymes in salivary injections. It has been observed repeatedly that fungal infections even in their incipient stages cause relatively much more extensive and injurious effects on the tissues of a strawberry root than hundreds of aphid punctures concentrated in a similar area. Fungal infection having been mentioned, it may be stated that in the many sections examined there was no indication that aphid injury provided an infection-court for fungi, nematodes, or other organisms.

DISCUSSION

At the outset of the present investigations, infestation of plants by the root aphid suggested several possibilities of pathological significance. The occurrence of the insects on roots showing typical root-rot symptoms suggested that their feeding *en masse* might cause necrosis of tissues and produce an effect similar to that resulting from the attack of parasitic fungi; or if not so important as primary causal agents, the insects might constitute one of a complex of interacting factors involved in the destruction of the roots. Histologic studies have shown that with the possible exception of the phloem, aphid punctures cause relatively little injury to the various tissues of the root through which they pass. Whether the salivary injection includes an enzyme capable of dissolving the middle lamella thereby facilitating the progress of the piercing organ is not known, but certainly there is little evidence of the presence of an irritating or toxic agent in the materials that constitute the setal sheath. Thus aphids do not cause root rot in the sense that parasitic fungi do, that is, by destruction of tissue at the immediate point of attack. But aphids may be present in such numbers and so exhaust the root of its products of assimilation that it may die or be reduced to a more or less permanent state of semi-flaccidity just bordering on wilting. In dry seasons, especially in plantations on lighter soils, infestation by aphids assumes an added significance, the more so if root rot is present, for then injury to the plant is cumulative under the combined attack of insect pest and fungous parasite.

Considerable intensive study of the feeding methods of representative homopterous insects has been carried out by various investigators. So far as aphids are concerned, most of the studies have dealt with those that feed on the stems or leaves of plants. Smith (13) who has recently reviewed the literature refers (loc. cit. p. 175) to the work of apparently the only investigator who previous to the present studies has studied the feeding

habits of root aphids, as follows, "Petri has shown that Phylloxera on the roots of the vine taps the cortical cells and does not reach the vascular bundles."

It is a well-known fact that aphids are concerned with the transmission of more plant virus diseases than any of the other insects and appear to have a special affinity for the spread of this type of disease. The present investigations have shown that *A. forbesi* Weed is present in commercial plantations in the more important strawberry-growing districts of central southern Ontario. Other recent investigations in which the writer has collaborated (1) have shown that certain of the leading commercial varieties of strawberries in Ontario, including Premier, Parson's Beauty and Glen Mary are infected with the virus of Yellow-Edge. What rôle (if any) *A. forbesi* has played or may play in the spread of this disease is a subject for further research.

SUMMARY

Following discovery of *Aphis forbesi* Weed on roots of strawberry plants in experimental plots at the St. Catharines laboratory, a survey revealed that the insect was present in at least 7 commercial plantations located in widely separated strawberry-growing districts of central southern Ontario. In the experimental plots mortality and lack of vigour of plants were clearly correlated with degree of infestation by the insect. The occurrence of root rot on many roots also infested by the aphids suggested a possible correlation between the two, but macroscopic and microscopic examinations indicated that injury by the insects bears no direct causal relationship to the afore-mentioned disease.

A study of the method of feeding of the insect has shown that it is a phloem feeder and that the path of the piercing setae through the hypodermis and successive underlying tissues, whether primary or secondary, to the phloem is intercellular. There is little evidence to suggest that the injected saliva exerts a lethal or irritating effect on plant cells contiguous to the stylet track. Thus, mortality and lack of vigour of infested plants are probably to be attributed to reduction of water supply (with solutes), to interference with translocation and to distrubances of metabolic equilibria rather than to direct injury to plant tissues by the method of feeding of the insect.

The discovery of eggs of the insect on roots *at a depth of several inches* in the soil is new, so far as is known, and suggests increased difficulties from the standpoint of control. Further, it implies that ants may not be solely responsible for the appearance of nymphs on the roots of plants early in the spring.

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SOME RESULTS OF MINERAL FERTILIZERS ON APPLE SEEDLINGS[1]

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During July 1932 it was observed that a great many trees in a block of over 1,500 Salome Seedlings, planted 14 feet by 10 feet in the spring of 1931, were showing severe injury to the foliage. This injury looked like a bad case of spray burn but as no spray had been used evidently some other factor was responsible. The reports of Wallace *et al.* gave some leads which were later confirmed, *viz.*, that the injury was due to potassium deficiency.

To check on this point and to ascertain what effect mineral fertilizers would have on these trees several tests were planned. It should be pointed out, however, that at no time were these fertilizer applications made with the idea of a planned experiment in mind. This explains why carefully measured amounts of fertilizer were not used. Some trees showed a peculiar foliage injury, supposedly potassium deficiency, and we were anxious to know if it could be corrected.

The soil, Vineland fine sandy loam, appeared quite uniform on the surface and nearly level. This block had been in meadow for years and had been tile drained and well prepared a few years before the seedlings were planted.

Forty trees in each of rows 2 to 11 were selected for these tests. There were 50 treated and 50 check trees in each plot. Since 1932 a few trees have died but 7 (out of 50 treated trees in Plot 3) constitutes the highest mortality. The arrangement of treated and check trees was in checker-board fashion and the plots were numbered consecutively from north to south.

Plot 1 received muriate of potash (and again in 1934).

Plot 2 received superphosphate.

Plots 3 and 4 received a combination of the two fertilizers in the same quantities as applied to Plots 1 and 2.

It was intended that Plot 4 should receive nitrogen later and thus be a complete fertilizer plot but the nitrogen was never applied. As surface applications of potash and superphosphate would not come in contact with the roots quickly, the soil was dug away from the trees for a radius of about 3 feet until the roots were exposed. The fertilizers were then applied in this area and covered over. No measured amounts were used but a good handful and a half, perhaps $\frac{1}{2}$ lb. of muriate of potash and two handfuls, about $\frac{3}{4}$ lb., of superphosphate were applied to each treated tree in its respective plot. This was done September 2 and 3, 1932. Plot 1 received additional potash, 2 lbs. per treated tree, in October 1934.

The response to these treatments was most striking. Where muriate of potash only was applied, careful observations during June 1933 showed

[1] Paper read before the Horticultural Group of the Canadian Society of Technical Agriculturists at Ottawa, June 29, 1938.

[2] Assistant in Hardy Fruit Work.

only occasional potassium deficiency symptoms. Superphosphate corrected the trouble only to a limited degree. Here the increased growth of the green manure crop (rape) immediately under the trees was the only appreciable effect. In the PK plots no deficiency symptoms showed on the treated trees but later results indicated that the leaf scorch, or the factors which cause it, were not as prevalent in Plots 3 and 4 as in Plot 1.

During July the injury throughout the orchard was more pronounced and several of the potassium treated trees which had showed no injury in June now showed some injury.

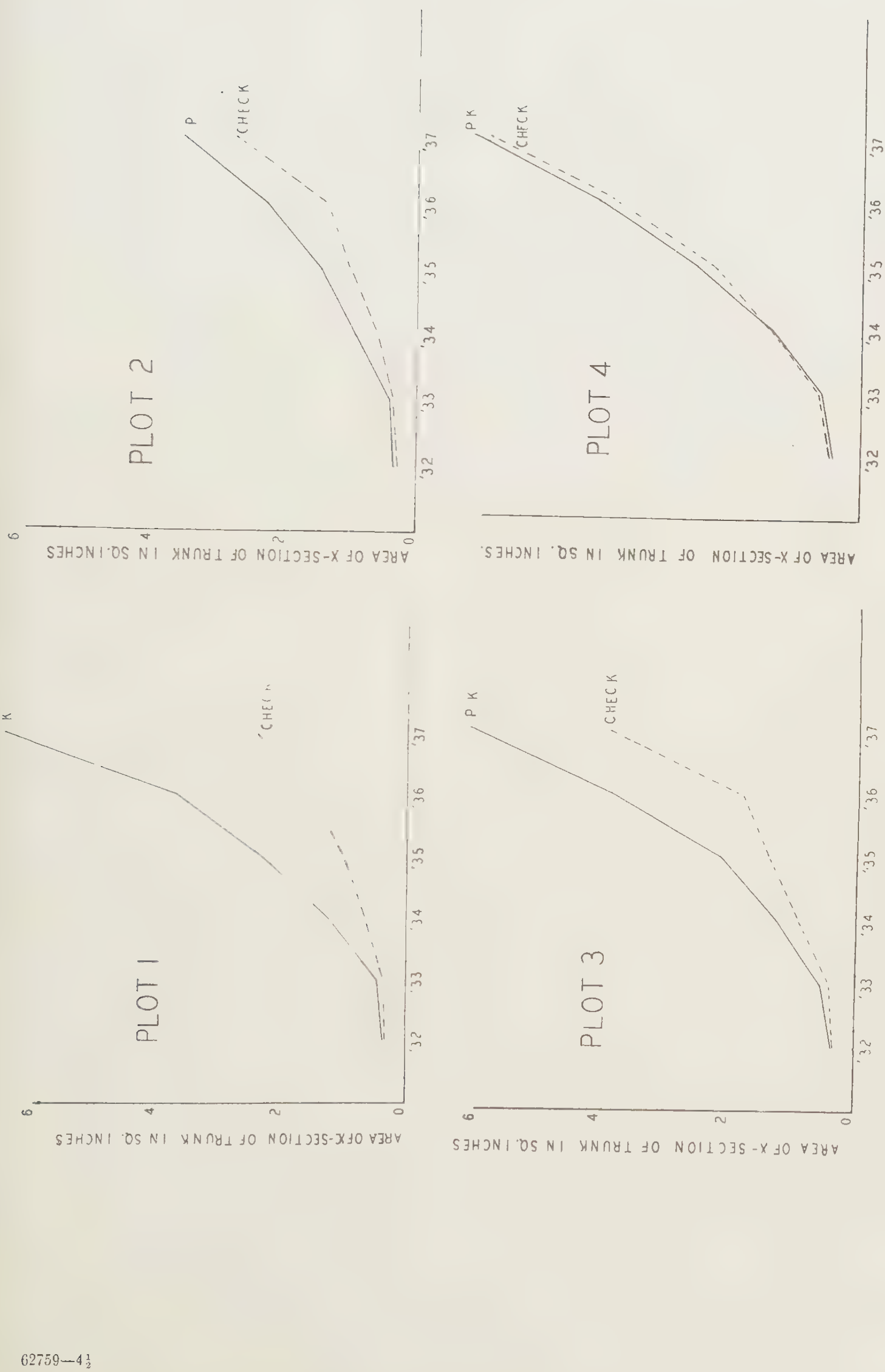
Table I gives some indication of the prevalence of the injury in the various plots and the extent of the improvement from fertilizer applications.

Table 1.—Number of trees in each injury classification July 16, 1933

Injury	Plot 1		Plot 2		Plot 3		Plot 4	
	Check	K	Check	P	Check	PK	Check	PK
Very bad	14	1	18	14	3	0	2	0
Bad	27	2	14	21	16	4	11	1
Slight	6	6	11	7	16	10	6	3
Traces	1	15	4	6	10	13	12	7
No injury	1	25	2	1	2	19	19	35
Total	49	49	49	49	47	46	50	46

To obtain the effect of the fertilizer on growth, diameter measurements were taken annually beginning in November 1932, at a marked point on the tree trunk. No diameter measurements were taken at planting time but as the trees were out of the same lot and planted at random it is unlikely that there were significant size differences between plots at that time. The average diameters in November 1932 were as follows: Plot 1, 0.68″; Plot 2, 0.61″; Plot 3, 0.68″; Plot 4, 0.77″. It will be noted that the trees in Plot 4 are somewhat larger than those in the other plots, indicating an early response to the better soil texture conditions which later were found to exist in that plot.

The response from the application of these fertilizers is shown in Figures 1 to 4. It will be noted that the addition of a potassium fertilizer has given a good growth response in Plots 1 and 3 but only a slight increase in Plot 4. The treated trees in Plot 1 are now the largest but these trees had additional potash in 1934. The most striking difference however is the relative growth of the check trees in Plots 1 and 4. On first thought one would assume that Plot 1 had been very low in potassium and that the addition of that fertilizer had created a marked response, whereas in Plot 4 the deficiency was not so great, and while a response was noted the gain over check had not been appreciable. However, an analysis of soil samples taken at depths, 0–6″, 6–12″, 12–18″, from five places in each plot showed Plots 1 and 4 to be equal as regards the presence of replaceable potassium (sodium chloride extraction). To obtain a more detailed determination, holes were dug near the centre of each plot to a depth of 3 feet and samples taken at 3-inch intervals to learn if there were differences in the lower



FIGURES 1 TO 4. Area of cross section of trunk in square inches showing the fertilizer responses in the different plots.

levels. Again both plots showed practically the same. In Plot 1, 0–3″ showed 10 p.p.m. of replaceable potassium and 5 p.p.m. for all the other depths whereas, in Plot 4 both 0–3″ and 3–6″ showed 10 p.p.m. and the remainder 5 p.p.m. Other chemical tests showed these plots to be very similar, thus indicating that while both were low in potassium the differences were not sufficient to explain such a marked contrast in tree size between the untreated trees in the two plots (Figures 1 and 4).

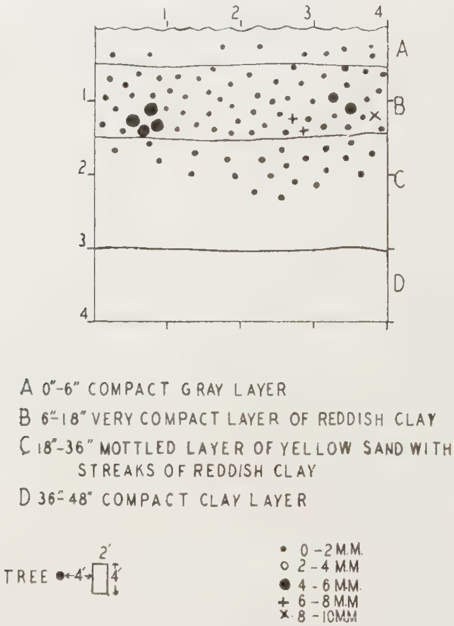


FIGURE 5. Root system of tree 5, row 9, one of the best in Plot 1, area of cross section of trunk (square inches) 10.8 (November 1937). This tree had potash in 1932 and 1934. Areas of cross section of trunk of check trees 4 and 6 are 1.1 and 6.2 square inches respectively. Area of cross section of trunk for all fertilized trees Plot 1 is 6.6 square inches.

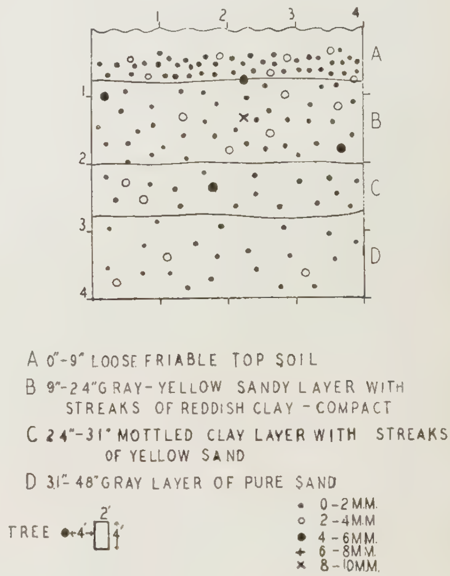


FIGURE 6. Root system of tree 32, row 2, only slightly larger than average for Plot 4. Area of cross section of trunk (square inches) 7.1. (November 1937). This tree had potash and superphosphate in 1932. Areas of cross sections of trunk of check trees 31 and 33 are 5.7 and 9.1 square inches respectively. Average area of cross section of trunk of fertilized trees Plot 4 is 6.2 square inches.

Recent investigations indicate that the differences between the two plots may be in the texture of the soils. Wallace (Journal Pom. and Hort. Sci. Vol. 6, page 280), stresses this point and states, "Mechanical analysis data are available for these areas and also for adjoining scorch areas and in every case the texture on the non-scorching area is superior to that in the scorched area when considered from the viewpoint of soil water condition. The 'available' potash found in the surface soil from the scorch area 18a is actually higher than that found in the surface sample from the adjoining scorch free area 18." Plot 4 is somewhat higher in elevation than Plot 1 which suggests better drainage, but at no time was there evidence of inadequate drainage in any of these plots. In digging to obtain the soil samples at the different depths, it was observed that there was a difference in the soil texture. In Plots 1 and 2 there was a layer of hard

clay near the surface which was not present in Plot 4. This hard layer varied greatly in thickness, from about a foot to a few inches, and as shown in Figures 5 and 6, influenced the depth to which the roots penetrated. In digging into this clay it was found to be quite pliable while moist but if exposed to the air soon became hard. In very dry weather it is possible a similar condition might occur in this layer and further hamper root development.

In Plot 1 the roots are found mostly in the upper layers whereas in Plot 4 they are found to a depth of 30″ or more (Figures 5 and 6). That poor texture of the soil is a factor in inducing this potassium deficiency condition is further illustrated in Plot 1 itself. One row in this plot is outstanding in growth. An examination of the soil under this row shows freedom from this clay layer, the soil being much the same as for Plot 4, and as a result a greater penetration of roots was possible.

SUMMARY

The conclusions from these tree tests are that the addition of a potassium fertilizer to a soil, on which the trees show potassium deficiency, definitely improves the condition of the foliage. However, potassium deficiency may be a secondary effect, *i.e.*, it may be an expression of some deeper trouble, and for an improvement in this respect some system of changing the soil texture, such as the use of a subsoiler of the Killifer type or, in some cases, heavy applications of barnyard manure, or other organic materials, should be considered. Where leaf scorch is present the use of potassium fertilizers can therefore be advised as a means of hastening the recovery of the trees, but to effect a permanent cure one should ascertain whether there is not a primary cause, such as poor soil texture, and if practicable, correct it as soon as possible.

ACKNOWLEDGMENTS

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HORTICULTURE IN NORTHERN ONTARIO[1]

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This paper is not intended to be technical in any way, but is planned to present the conditions in one of the large pioneering districts of Canada, to point out that horticulture should be the basis upon which to build a programme of agricultural development, and to show that such a programme is entirely practical in Northern Ontario.

On all sides, I have seen it assumed that horticulture is of little importance in the life of a pioneer. It is something to leave to the wife, something to think of "getting going" only when other lines are well underway, in other words, a luxury. This, I believe, is an entirely false assumption, the truth being exactly the opposite.

Let us briefly survey the territory known as Northern Ontario, and examine a few of its salient characteristics. It is that part of Ontario which is north of the great lakes, and is separated from Old or Southern Ontario by a line that runs from the Georgian bay across to the Quebec boundary. To the east lies Quebec, to the West Manitoba and to the north, the shores of James and Hudson bays.

Railways run through the district and are well located for future development. In the southern part, these consist of the C.P.R. and C.N.R. lines running from North Bay to Port Arthur and on to Winnipeg, and farther north, across the water shed, the northern line of the C.N.R. runs from the Quebec border through Cochrane, Kapuskasing, Hearst, Nakina and Kenora on to Winnipeg. Other railway lines run north, one from North Bay through Cochrane to Moosonee on James bay, and another from Sault Ste. Marie to Hearst. These are the Temiskaming and Northern Ontario and the Algoma Central railroads respectively.

While geographically, the territory runs up to the great bays to the north, it is believed that agricultural land gives way to rock and marsh about 50 or 100 miles north of the northern railway, though this is largely a matter of conjecture and not based on actual knowledge.

The area circumscribed by this northern boundary is approximately 70 million acres. Men who know the whole territory thoroughly, estimate that at least one-half is arable. However taking a more conservative estimate of one-third of the area as being of agricultural value, at the usual Ontario survey of 100 acres per lot, there is room for 200,000 holdings. At present some 20,000 are taken up, so that there are great areas still open for settlement.

The best land in southeastern and southwestern parts has been taken up; the northwest is very broken and rocky, and therefore the greatest room for expansion lies in the northeast. As this is the part in which the Experimental Station at Kapuskasing is located, and the one with which I am most familiar, my remarks may have a more direct bearing on conditions in this section, though applicable to other parts in general.

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[1] Read before a meeting of the Horticultural Group of the C.S.T.A. at Ottawa, June 27–July 2, 1938.
[2] Assistant to Superintendent.

In its natural state, the whole country is covered with a dense forest of spruce, balsam, poplar and birch. The ground is usually covered with a mat of moss often two feet thick which acts as a perfect insulator, and prevents the soil from thawing out to any depth. In these respects, the district differs greatly from most other pioneer districts in Canada, except that of Northwestern Quebec, regarding which these comments apply with equal force.

Within these boundaries are situated large pulp and paper industries, and the extensive mining development that is so well known. Around these, villages, towns and cities have grown up which offer excellent markets for horticultural as well as other products. In this respect also Northern Ontario and Northwestern Quebec differ from other pioneering communities.

CLIMATE

The agricultural portion of Northern Ontario may be termed a transitional zone between Eastern and Western Canada. It lies in a more northerly latitude than the settled parts of the East, but south of the Prairies.

For instance, the area along the northern line of the C.N.R. which approaches the northern limits of agricultural land is approximately on the same parallel of latitude as Winnipeg or Vancouver.

Geographically this territory is not far north, but climatically it is, for the isotherms curve sharply southward following the shores of Hudson and James bays. Temperature records taken by the Experimental Farms Service illustrate this forcibly. At Ottawa, the mean annual temperature is 41.7° F., at Morden in Manitoba 37.9, at Beaverlodge in the Peace River Country of Alberta 35.4, while at Kaspuskasing it is 32.5. Thus Beaverlodge on a latitude 300 miles to the north and Morden approximately on our latitude, both enjoy a warmer climate than ours, as of course does Ottawa.

The growing season is short. At Kapuskasing, work on the land usually begins about the middle of May, though this may vary two weeks in either direction. Spring frosts occur quite late, the average date being June 17, and fall frosts, severe enough to stop growth, occur about September 1. Thus a period of 75 to 80 days without frost can be expected. These late and early frosts are caused by the proximity of the cold waters of James and Hudson bays, and the frozen condition of the forest soil, for even on the warmest days should the wind turn to the north or northwest, the temperature drops sharply and the freezing point is often reached.

It has been observed, however, that the prevalence of such frost is becoming less as the clearings in the forest become larger.

Precipitation is adequate and well distributed throughout the growing season, though we often experience spells of very wet weather, and on the other hand, any period without rain soon develops into a drought.

Snowfall is reasonably heavy and affords excellent protection to perennial plants. At Kapuskasing, it averages 88 inches per season.

In the more southerly and western parts, the growing seasons are more favourable, particularly in the proximity of the great lakes.

SOIL AND TOPOGRAPHY

The soil varies considerably, but is mainly a heavy clay lacking in organic matter, though thickly dotted with small areas of muskeg or black muck as it is called locally. Some comparatively small areas of loams or sands are encountered, and are very good for horticulrural purposes, especially potato culture. The clay, however, is very heavy and requires the addition of large quantities of organic matter to make it suitable. This can be done on a small scale for the family garden, by working in a good coat of black muck and sand.

The topography is gently rolling and plentifully supplied with creeks and rivers. These afford good natural drainage outlets.

Drainage itself is a major problem. Subsoil or tile drainage has not been found satisfactory and entails a larger outlay of capital than can be afforded by a pioneer community. It has been found however, that the Richard system of surface drainage serves very well and does not entail any special capital outlay.

The height of land runs east and west about midway through the country, and thus drainage is either south to the great lakes or north to James bay.

In the western part the soils tend to be lighter and gradually merge into the prairie soils of Manitoba.

SETTLEMENT

In Northern Ontario settlement of the land can be seen in all stages. In the older sections to the south and west which have been settled for 30 years or more, communities of farmers are well established; fine buildings have been erected and sound horticultural programmes have been developed, particularly with regard to vegetables. For the most part these areas were settled by people having an agricultural background either Canadian or European.

In the north, the settlements are more recent, none being older than 20 years and many 5 years or less. In this part farms may consist of anything from 100 acres under cultivation to lots of virgin timber. The majority of settlers are either bush workers who have taken up lots with the main intention of cutting pulpwood for the pulp and paper mills, or city workers who have been brought in on relief projects and "back to the land" movements. Neither group has an agricultural background, very few individuals have any knowledge of farming or horticulture, all are easily discouraged when failures occur and, as yet, are indifferent to the possibilities before them.

It is in this stage of settlement that horticulture should be occupying a fundamental place in the programme, but only in isolated cases is it assuming its rightful place and proving its value.

Where clearing operations are just beginning, the first land brought under cultivation should be a garden. The small area requisite can be cleared rapidly and worked without the capital investments that larger acreages require in the way of machinery and horses. Such a garden immediately solves in a large measure the problem of food for the settlers' family, protects their health as nothing else can, and makes them largely

self supporting from the very beginning. In this way, the usual slender capital they possess can be used for constructive development rather than for temporary maintenance.

Along with this, the material side of horticulture, there is another which is equally important. Throughout the whole of Northern Ontario there is need for a progressive and aggressive programme of tree planting and home beautification.

In a land of natural forests, trees are being destroyed ruthlessly and whole communities are practically denuded to-day. This is quite understandable, however much it may be deplored, when the reasons are examined. Fire, the only practical tool at the disposal of the land clearer, is no respector of tree growth in its path, however much it may be desired that such be preserved. Then again, forest trees when deprived of the shelter of the forest will not stand, but are blown down by the high winds that are common. This is due to the shallow root system of forest grown trees caused by the frozen condition of the soil already mentioned. In addition to this, the viewpoint of the individual who clears land becomes warped, if it may be so expressed. Tree growth is the first and most serious obstacle which confronts him when carving out a farm for himself. Trees become the arch enemy, and the only thought is to destroy them. It is only after the forest has disappeared that realization comes of its value as a shelter from the bitter winter winds. Tree planting in shelter belts and windbreaks is the solution and needs to be encouraged as much as possible.

The need for beautification can only be realized by one who has travelled the country. Farm buildings stand stark and naked, the villages and towns consist of huddles of unpainted buildings, an eyesore and a blot upon the landscape. Those interested in establishing a permanent population in the country are realizing more and more forcibly the necessity of improving the appearance of premises so as to develop a pride of ownership without which a feeling of permanence cannot be born.

HORTICULTURAL MATERIAL

The question naturally presents itself as to what horticultural crops can be grown under the conditions existing in this district.

Fruit

As yet small fruits are the only ones of any value. Raspberries, strawberries, black and red currants do extremely well, but gooseberries are not so successful. These naturally ripen later than they do in the southern parts of Ontario and Quebec, thus affording the possibility of producing fruit for a late market in the cities to the south as well as in supplying the requirements of our own towns and cities which we are not doing now.

Blueberries grow wild, and large shipments are made to the south, this product reaching as far as Chicago and New York. The centre of this production is on the sandy moors south of Cochrane on the T. and N.O. railroad.

In the past two years the Ontario Department of Agriculture has been organizing the handling of this fruit and supervising the quality of the product shipped out. This has increased sales and netted larger returns to the pickers.

Large fruits have not yet proved successful, only four varieties of crab apples having been found hardy enough to withstand the winters at Kapuskasing.

In the western end of the district in the country around the head of the great lakes, some standard apples, namely, Hibernal, Wealthy and Duchess, are giving a fair measure of success but not on a commercial scale.

Selected native plum and cherry seedlings have been tested, but nothing has been found as yet that will withstand the combination of winter cold and heavy poorly drained soils. Many varieties of fruit trees that are hardy on the prairies far north of our district, have not proved to be of any value to us.

Vegetables

A surprisingly wide range of vegetables can be grown. This includes all the common ones, except such long season and warmth loving crops as cucumbers, squash, egg plant and tomatoes, although large crops of green fruit are obtained of the last named. Sweet corn succeeds occasionally if the earliest maturing varieties are used, but cannot be relied on.

Potatoes can be grown throughout the district, and as already mentioned the areas of lighter soils are particularly suitable. The quality of the product of such areas is hard to surpass, and there is a bright future for this crop, when marketing organization is developed. Potatoes produced in Northern Ontario have been consistently in the prize money at the Royal Winter Fair.

Beyond the production for home use, fairly large markets for vegetables are available in the cities of Sudbury, North Bay, Fort William, Port Arthur, Timmins and Kirkland Lake and in the towns and villages around the pulp and paper mills and smaller mining camps. These are being supplied with produce from the south, which comes in by the train load and truck load daily to each centre. In the light of our success at Kapuskasing, there is no valid reason why local production should not supply the requirements of these markets in a large measure.

The differential of freight rates and the quality of freshness would make the product readily saleable and profitable to the grower who goes into the business in a businesslike way. The quality of the product is excellent owing probably to the rapid growth that takes place once the season gets underway.

Ornamental Plants

The variety of trees and shrubs is not as great as with other plants. Naturally the best species are those that are native. These include spruce, balsam, tamarack, Jack pine, cedar, birch, poplar, willow and wild cherry, all of which can be obtained without difficulty in the bluffs and forests.

At Kapuskasing we are finding that rock elm and white ash are thriving very well. These are not indigenous.

Along the southern boundary of Northern Ontario, the coniferous forest of the north merges into the deciduous forest of the south. Here,

maple, American elm and other hardwoods are found and a species of oak grows 100 miles north of this transitional zone.

For shelter belts, mixed plantations of willow, poplar and spruce are very satisfactory as the former grow rapidly and give quick shelter, while the spruce comes along more slowly but will live much longer.

Indigenous shrubs consist of mountain ash, dogwoods, highbush, cranberry, elderberry, Saskatoon berry and wild roses, all of which make an attractive growth when suitably used. Introduced species which are proving entirely hardy are mountain pine *(Pinus mugho)* caragana both aborescens and pigmyea, Virburnum lantana, Spirea van houttei, Tartarian honey-suckle, Siberian lilac, Rosa rugosa, Japanese barberry and cotoneaster. For hedges spruce, caragana, Saskatoon berry, dogwood, willow and lilacs are excellent. Other trees and shrubs are being tested at the station at Kapuskasing, but their survival has yet to be determined.

In climbing plants wild bitter-sweet is being used and climatis is found hardy in sheltered locations, but the most satisfactory is the Virginia creeper (Ampelopsis quinquefolia).

Among flowers and herbaceous plants, a goodly array can be used. Normally all the common annuals thrive, but the majority must be started in hot-beds so as to extend the length of the season.

Great showings of anthirrhinum, schizanthus, clarkia, petunia, sweet peas, poppies, etc. are usually obtained, although in the worst seasons they may be set back by frost.

Many perennials and biennials thrive very well, particularly in sheltered locations or in places where the normal snow cover is not swirled away by wind. Peonies, aquilegia, delphiniums, poppies, pansies and so forth are successful, and even species that are much more tender will survive if well covered with snow late in the spring. At Kapuskasing we have found that killing usually occurs in the spring if the snow goes early and the plants are exposed to a period of frosty weather, with the consequent soil heaving that takes place.

Some enthusiasts are having remarkable success with gladiolus and even dahlia, a local fancier of the latter having obtained a place of high merit at the Century of Progress Exhibition held in Chicago with one of his varieties.

Flowering bulbs such as daffodils, tulips, etc. give excellent satisfaction if planted where there is a reasonable snow cover during the winter.

This brief summary of the horticultural plants that thrive at Kapuskasing in the most northerly section of Northern Ontario, shows that there is an adequate range of material with which to develop a sound programme.

That this can be added to and improved upon goes without question. Therein lies a large field for those who are interested in experimentation and plant improvement. Many individuals are doing excellent work along such lines and doubtless their work will bear abundant fruit in due season, not only in new and more suitable varieties, but by the example of their courage and initiative.

Horticultural societies are being formed in many communities, though chiefly in our towns and cities. Their efforts are beginning to be mani-

fested in the improved appearance of the centres in which they are established.

In concluding may I again lay stress upon the value of horticulture to the pioneer of Northern Ontario. The establishment of a garden of vegetables and small fruits, helps to overcome the question of being entirely dependent upon one's financial resources during the period of bringing the land under cultivation, a slow and arduous process in Northern Ontario.

Trees planted for windbreaks not only afford material comfort, but along with shrubs and flowers turn the crudest dwelling place into a home. They become a source of pride to the owner and an inspiration toward the improvement of his living conditions. They inspire a love of his surroundings and constitute the tie that binds him to a new country. They turn his farm into a home, and it is only by building homes that any country can develop a prosperous and stable agricultural community.

BOOK REVIEWS

PROCEEDINGS OF THE FOURTH INTERNATIONAL LOCUST CONFERENCE AT CAIRO, APRIL 22, 1936.

This conference which was attended by delegates from twenty-three countries was the largest yet held.

A section of the report is devoted to the proceedings and resolutions and is followed by the scientific papers presented by the delegates. The former is printed in both English and French and individual papers in either language.

Statistics showing the losses by locusts are given in order to arrive at an estimate of the economic importance of the problem. Dr. B. P. Uvarov brought the phase theory, which he originally propounded, up to date by a paper on its biological and ecological basis. It was pointed out that "The transformation from the solitary into the gregarious phase is dependent upon a combination of a number of ecological factors, such as climate, vegetation, etc., which vary according to the species concerned and the general conditions of the region in which it occurs". "The first step in a sound preventive policy should, therefore, consist in the organization of detailed studies of the habits and ecology of each species of locust and grasshopper of economic importance in each natural region, with particular reference to the factors inducing phase transformation." This was the keynote of the conference and the mainstay of the work in the Old World. In North America, where gregarious grasshoppers do not occur, there is an approach to phase transformation and a similar research program being carried on in Canada and the United States was endorsed as sound.

Contrary to the common opinion the conference pointed out that "in the case of many species of locusts and grasshoppers, their excessive multiplication, their spread, and their formation of outbreak areas, have been furthered rather than hindered by man's activities". Further research should lead to an understanding of these factors and their modification as a means of control.

Baits poisoned with sodium arsenite were the most satisfactory and economical but further research is needed to find a less dangerous poison. Aeroplane dusting of flying swarms was satisfactory but no information was given on this method of spreading bait.

Further studies on the natural enemies of grasshoppers are desired.

The problems presented by the Desert, Red, Brown, South American, Oriental, Moroccan and Italian locusts, and grasshoppers in North America and Australia are discussed.

R. D. BIRD

FISHER, R. A., and F. YATES. Statistical Tables for Biological, Agricultural, and Medical Research. Oliver and Boyd, London, 1938.

Research workers who wish to apply statistical methods to the organization and analysis of their experiments will welcome this publication. The tables previously available only through Dr. Fisher's books and reprintings by other authors are reproduced here, and have been extended

in order to include a greater range of values. The tables of t and χ^2, for example, now give the values of these statistics at the 0.1 per cent point, and the table of z has been extended to include the 20 per cent point, and additional values for n_2 are also given. For each value of z tabulated, there is given on the opposite page the corresponding value of the "variance ratio", which on this continent is commonly known as F.

There are a number of other tables which the authors have found by experience to be extremely valuable in a statistical laboratory. Some of these are:

Latin Squares—with instructions as to the correct method of selecting squares at random for experimental work.

Orthogonal Latin Squares—for use in setting up balanced incomplete block experiments.

Orthogonal Polynomials—for curve fitting.

Squares, Square Roots, and Reciprocals—set up in a very convenient form for the purposes of the statistician.

Random Numbers—These have been prepared in such a way as to ensure the randomness of the numbers and have been thoroughly tested. They have been set up in a convenient form and should be extremely useful for all randomization work.

The first part of the book contains explanations of the tables and numerous examples of their application. The latter will be found particularly useful in learning the many uses of the tables.

C. H. Goulden.

W. T. Easterbrook. Farm Credit in Canada, Department of Political Economy, Uuiversity of Toronto; foreword by H. A. Innis. The University of Toronto Press, Toronto, 1938. 254 pages including appendix. Price $2.50.

In this volume, which is No. 2 of the Political Economy Series published by the University of Toronto Press and the Maurice Cody Foundation, Dr. Easterbrook has provided a valuable foundation and background for further research work in the field of agricultural finance. A study of the history of the financing of agriculture, this book is divided into two parts, the first dealing with farm credit up to the advent of provincial lending agencies in 1917, and the second showing the part played by governments in the provision of credit to farmers following the war.

The early status of the agricultural industry is described as follows: "Encouraged chiefly as a means of ensuring possession of the country and as a support to the early fisheries and the fur trade, farming remained primitive and subsidiary over a long period." In tracing the development of agriculture in Canada, the author describes the stages through which the industry has passed up to the present time. In the early settlement of Canada France based the whole scheme of her colonization upon the idea of benevolent overlords and established a replica of her feudal system, settlement being encouraged through the medium of generous grants from the Crown. In those areas which were under the British rule, the main

objective of early settlement was that of defence. During that part of the period prior to 1800, agriculture approached almost complete self-sufficiency and little cash outlay was required. With the emergence of agriculture as a primary industry during the early part of the 19th century the demand for greater credit facilities arose. During the early years this need was supplied largely by merchants, later supplemented by building societies. These societies were later replaced by more permanent loaning institutions many of which drew a large part of their funds from abroad.

In discussing western expansion the author goes on to show how a credit stringency resulting in part from the withdrawal of British funds from the Canadian investment market led to direct government intervention in the field of farm credit. Many interesting contrasts between the development of agriculture in Canada and the United States with particular regard to agricultural credit are pointed out by the author.

The remainder of the book is given over to a discussion of the various provincial and federal measures designed to aid agriculture through the extension of credit, in chronological order by provinces and with an appraisal of their influence.

The final chapter describes government intervention in the adjustment of farm indebtedness and its significance.

In his conclusion, referring to government activity in the field of agricultural credit, Dr. Easterbrook states that: "In general, lending has been scattered, with no attempt at co-ordination of the different types of advances. The study of the credit needs of the different types of farming, and the task of co-ordinating credit policies with others relating to agriculture also remain as considerations for the future." Further on he states that "The state is faced with the alternative of furnishing the lead to private capital, or of undertaking itself to meet the credit requirements of agriculture."

Descriptive of events concerned with the provision of credit in the development of the agricultural industry in Canada as well as analytical with respect to the significance of these events, this book is of particular interest to students of economic history and farm finance. Of special interest are the 85 pages of notes which are evidence of the amount of painstaking labour which Dr. Easterbrook put into his study.

S. C. Hudson.